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Seismic Safety Element

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SEISMIC SAFETY ELEMENT

Seismic Safety Element
being a part of the
Contra Costa County General Plan

prepared by the
Contra Costa County Planning Department
December, 1975

Adopted October 28, 1975

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CONTRA COSTA COUNTY PLANNING DEPARTMENT

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HIGHLIGHTS

SEISMIC SAFETY ELEMENT HIGHLIGHTS

Contra Costa County, like all of the San Francisco Bay Region, lies within a geologically active and dynamic portion of the earth's crust. The Bay Area is laced with earthquake faults, including the San Andreas fault which passes west of San Francisco and the Hayward, Calaveras and Concord faults which pass through Contra Costa County. The seismic history of this area clearly indicates that future earthquakes capable of producing great damage and disaster are inevitable, and that a major cause of earthquake damage in the County resulting from, say, either a great earthquake on the San Andreas fault or a moderate magnitude earthquake emanating from a fault in the County would be ground shaking and seismically-triggered ground failure.

Potentially hazardous conditions in Contra Costa County run the gamut of hazards found in California. Some are primarily seismic in this nature, such as earthquake faulting and ground shaking, while others are only secondarily related to seismicity. For example, the sloping hillsides of the Briones Hills and Diablo Range are pock-marked by a succession of large and small, geologically-recent slides, many of them highly unstable. The potential for seismically-induced landslides is very pervasive throughout these hilly portions of the County. The historic record is also clear in pointing out the special problems posed by the soft, water-saturated sediments which underlie the margins of the San Francisco Bay estuary and Delta lowlands. These problems include the potential for subsidence, seismically-triggered ground failure, and flooding.

The Seismic Safety Element attempts to view seismic safety comprehensively, spanning a wide range of seismic related conditions and matters. These concerns include the following:

1. Identification of Potentially Hazardous Areas. The identification of areas which are potentially hazardous and require special consideration in land planning and building is of fundamental importance in seismic safety planning. Accordingly, the Element recommends the preparation of an administrative map series, including a geologic map, seismic susceptibility map (i.e., damage susceptibility), liquefaction potential map, slope stability map, and seismically-triggered flooding map. The basic approach recommended is to compile existing information developed by the U.S. Geological Survey, California Division of Mines and Geology, University studies and geologic reports prepared by consultants for development projects. As such the maps would be a catalogue of existing information and would aid in project reviews performed by the County Planning Department.

2. General Plan Implications. The Element directs that seismic safety factors be prominently considered during General Plan reviews, which are periodically performed for all planning areas. The Element encourages the retention of high-risk areas in low occupancy or in open forms of land use. It discourages the expansion of public commitment to development of high-risk areas without appropriately detailed geologic and/or soils information.
3. Project Review Implications. The Element directs that geologic and related studies be performed and seismic safety factors be prominently considered for both public and private projects. Reliance is placed, to a considerable extent, on the project sponsor to respond to the findings of geologic and/or soils investigations. In this regard it is significant to note that, by intention, the requirement for studies has been made sufficiently broad to allow for the exercise of professional judgment. The Element also directs that subdivision and zoning ordinances be amended to identify seismic safety as a significant public purpose in the exercise of subdivision and zoning requirements.
4. Seismic Safety Administrative Referral Panel. Because the administration of seismic safety requirements involves a wide range of technical knowledge and the exercise of judgment and interpretation, the Element proposes that the County consider the creation of a panel of experts to assist in its administrative process.
5. Post Disaster General Plan Review. The Element directs that the Planning Department conduct a review of the General Plan following any earthquake which produces damage in the County, with special emphasis on affected areas. Geologic, seismic and earthquake engineering information developed in the aftermath of such an earthquake should be prominently considered during this General Plan review.
6. Building Codes. As a result of knowledge gained from studies of recent earthquakes and other research, several areas of concern have been identified in the existing seismic design provisions of the Uniform Building Code. In view of these deficiencies, the International Conference of Building Officials has prepared the "1976 amendments" to the Uniform Building Code. This package of revisions addresses some, but not all, of the subject of concern. The Element recommends that these amendments be adopted and enforced as soon as possible.

7. **Structural Hazards Study.** A major technical impediment to the development of a program to reduce the hazard posed by older, collapse-hazard buildings is the unavailability of comprehensive and systematic inventory information. If the state does not prescribe a program to study hazardous structures within two years of the County's adoption of the Seismic Safety Element, the Element directs the Planning Department to draft a work program to conduct its own study.
8. **Emergency Response Facilities.** Certain public and institutional services are needed immediately following an earthquake to aid the injured, prevent additional casualties, and protect property (e.g., hospitals, police and fire stations, emergency service headquarters and communications installations). If local emergency plans are to be put into effect, it is imperative that these facilities survive the earthquake and remain operative in the aftermath. Basically, the Element indicates evaluation of the seismic survivability that existing critical facilities be given the highest priority in future structural hazard study. The Element also recommends that critical structures not be located in "high-risk" areas. Where it is in the overriding public interest to locate critical facilities in such areas, special precautions should be taken to enable those facilities to withstand anticipated hazards.
9. **Evaluation of Seismic Risk.** Since the total elimination of risk from seismic causes is not possible, it would be desirable to "price" the costs and benefits of alternative seismic safety plans and programs in terms of their comparative abilities to save lives and protect persons and property. However, this kind of cost-benefit quantification is not possible at present so the determination of acceptable risk and the selection of acceptable seismic safety programs must be made qualitatively. With particular reference to the structural aspects of seismic safety, the California Legislature's Joint Committee on Seismic Safety advocates an approach to determining acceptable risk which is summarized in Table 9. The Element regards this approach as a reasonable guideline in determining costs for its own projects and in setting standards for private construction.

In summary, it is important to recognize that the policies and recommendations of the Element, individually or in combination, are intended to protect lives and minimize injuries and property damage; but it is obvious that since several recommendations point to the need for future studies, the goals of the Element

are not going to be accomplished in the near future, or with present means. Rather, it is expected that implementation of the Element and other public programs will result in a continuing reduction of risks to persons and then to property.

INTRODUCTION

The Safety Report is a part of the County Council Safety Committee.

The Safety Report is a report to the public, setting out the findings of the County Council's investigation into the accident, the circumstances of the accident, the actions taken by the County Council to prevent a recurrence of the accident, and the actions taken by the County Council to improve the safety of the road. The report is a part of the County Council's commitment to the public to provide a safe and secure environment for all.

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PURPOSE

This Seismic Safety Element is a part of the Contra Costa County General Plan.

The Seismic Safety Element is a public policy for relating the County's programs for land use planning, the provision of public improvements and the development or redevelopment of land (land planning) to the County's seismic characteristics. Although attention has been given historically to the performance of buildings and structures during earthquakes, comparatively little attention has been given to the subjects of how land uses should be distributed, or building developments laid-out, on a seismically active landscape. This is the realm of the Seismic Safety Element, and it promises to be a field for innovation for years to come.

The Seismic Safety Element is particularly important to Contra Costa County because the County is located in one of the most seismically active areas of California. It is subject to severe ground shaking, ground failure, and flooding from earthquakes occurring both within the County and the Bay Area, and it is additionally subject to ground rupture from earthquakes on a number of faults located within the County. Further, the potential for earthquake damage is increasing as the County grows in population and as development extends into higher risk areas such as certain of the hill areas and natural floodplain areas.

This is Contra Costa County's first Seismic Safety Element. Because it is largely based on available information, it is expected to be supplemented and made more comprehensive as its implementation program is carried out and as more detailed information is produced.

SEISMIC SAFETY GOALS

The Seismic Safety Element was prepared to further several long-range and on-going goals of Contra Costa County; these are:

1. To prevent the loss of human life from seismic causes.
2. To minimize serious injuries to human beings from seismic causes.
3. To facilitate the provision of essential services following a disaster from seismic causes.

4. To reduce damage to property from seismic causes consistent with (balanced against) financial capability, quality of life, and environmental quality.
5. To facilitate recovery from a disaster from seismic causes.

The objectives, policies, and recommendations of this plan are intended to address these goals.

GENERAL OBJECTIVES

The Seismic Safety Element is intended to serve the following purposes:

1. To comply with Section 65302 of the California Government Code requiring cities and counties to include Seismic Safety Elements in their General Plans.
2. To provide a basis for better considering earthquake hazards and other hazards in public and private decision making.
3. To ensure that knowledge of earthquake hazards, and other geologic hazards are given appropriate consideration in the General Plan and its several component elements.
4. To provide a basis for contingency planning for redevelopment following a severe earthquake or other disaster.
5. To provide a basis for including knowledge of earthquake hazards and other existing or potential hazards into consideration in zoning, subdivision, and other development ordinances.
6. To provide a basis for including knowledge of earthquake hazards and other hazards in mandatory referrals, environmental impact statement reviews, and other project reviews.
7. To provide a basis for updating local emergency services plans in terms of post-disaster response and recovery.

ORIGIN OF THE SEISMIC SAFETY ELEMENT

The requirement that California cities and counties address seismic safety in their general plans is a direct result of the substantial increase in man's knowledge of the causes and effects of earthquakes in recent years. Along

with the understanding that earthquakes are caused by on-going geologic processes, and are not random "acts of God", has come a conviction that society should use its technical knowledge to minimize their effects. This is particularly true for those areas of the earth where history records that most earthquakes have taken place and where geological science tells us that most earthquakes will happen in the future.

California lies in one of those belts of the earth where the landscape is still being formed by the geologic forces that generate earthquake activity. Worldwide, the U.S. Coastal and Geodetic Survey reports approximately 5,000 earthquakes per year. California annually can expect to experience more than 500 earthquakes which will be strong enough to be recorded by general purpose seismographs. (It should be recognized that the monitoring of earthquakes in California is much better than in the world generally but seismologists believe that approximately one to three percent of the world's earthquakes occur in California.)

The State's experiences with earthquakes have caused it to enact laws that have already saved lives and minimized injuries, and to create programs that promise substantial benefits in the future. One of these programs was the California Legislature's Joint Committee on Seismic Safety study effort, which saw some of its recommendations implemented even before it published its report. The requirement for General Plan Seismic Safety Elements, enacted in 1971, originated with this group.

TECHNICAL BACKGROUND REPORT

The Seismic Safety Element is based on the Seismic Safety Element Technical Background Report which is a staff study by the County Planning Department. The Technical Background Report was made to compile technical and methodological information too voluminous to include in a policy report. Its intent was to assemble information on seismic safety and organize it relative to Seismic Safety Element requirements. From this information were derived findings and policies and recommendations which have been carried over into this Seismic Safety Element. The supporting materials in the Technical Background Report however, are only summarized in this Element. A draft of the Technical Background Report was reviewed by an advisory group of experts and citizens before it was published.

EARTHQUAKE OVERVIEW

Before proceeding with the major parts of the General Plan Element, it is appropriate to discuss the characteristics and effects of earthquakes to ensure

that users have a common basis for understanding the natural processes addressed in this Seismic Safety Element.

The Nature of Earthquakes

Earthquakes are sudden releases of strain energy stored in the earth's bedrock. The energy originates in the geologic forces which cause the continents to change their relative positions on the earth's surface. The process is called "plate tectonics" and will be discussed later. The earthquakes represent adjustments between these plates as they slip past one another to establish a new equilibrium. In the process, the features of local landscapes are being created as mountains and ridges are being raised up and as valleys are formed.

Energy can be stored in the earth's crust because its bedrock formations are more or less elastic. Under pressure they may be permanently distorted or they may store the energy for later release. Like the hard steel of springs or the wood of bows, they can bend under pressure and hold the strain energy. They can release the pressure slowly, or they can "break" and release it rapidly (and often destructively).

Earthquakes occur when either the resistance of friction between rock masses is overcome along an existing crack (fault) or when the shear strength of the hard rock material is exceeded, and it "snaps". Similar to the breaking process of certain metals or woods, the main break of an earthquake may be signaled by foreshocks and followed by aftershocks.

The energy being received in local rock formations may be released almost as soon as it is generated or it may be accumulated and stored for long periods of time. The individual releases may be so small and gentle that they are detected only by sensitive instruments or measured as tectonic "creep", or they may be massive and so violent that they cause destruction over vast areas.

During an earthquake, opposite sides of the crack (fault) move relative to one another. The displacement may originate at great depth in the earth and be absorbed within the earth or it may propagate to the surface. The relative movement between the rock formations on either side of the fault, may be horizontal, vertical, or combinations of these.

The Cause of Earthquakes

Earthquakes are thought to be a form of local adjustment to a worldwide geologic process called "continental drift" or "plate tectonics". It has

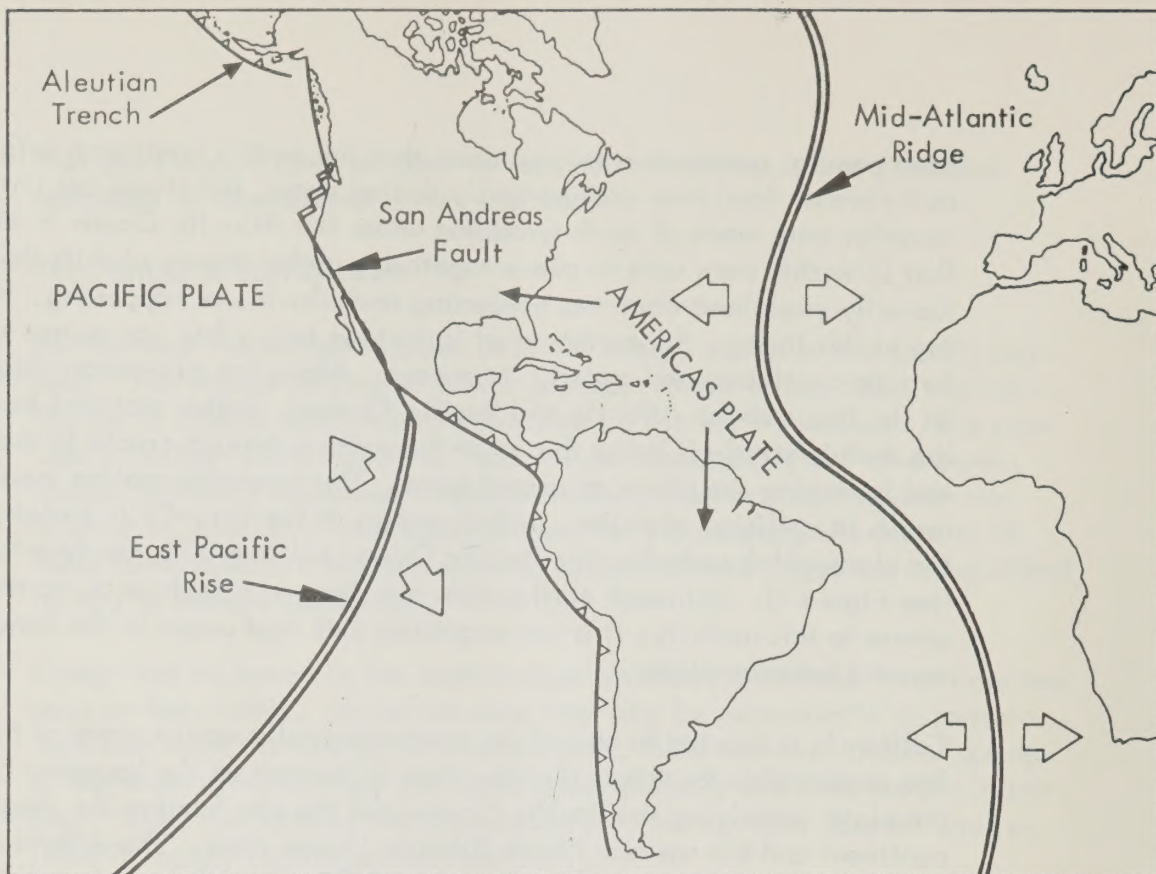
been popular speculation for centuries that the earth's continents originated as a common land mass and gradually drifted apart, but it was not until discoveries were made of earth spreading under the Atlantic Ocean in the 1960's that scientists were able to piece together a global theory of drift that satisfactorily explained what was happening and why it was happening. According to this theory, the earth's crust is divided into a few vast plates which form its continents and underly its oceans. Along the mid-ocean ridge systems on the floors of the Atlantic and Pacific Oceans, molten material from within the earth's mantle is being forced to the surface through cracks in the crust and is causing the plates to spread apart. This spreading motion inevitably results in collision of plates, such as occurs at the Peru-Chile trench, where the plate which underlies the Pacific Ocean collides with the Americas Plate (see Figure 1). Although earthquakes may happen anywhere on earth in response to this activity, it is not surprising that most occur in the zones of contact between plates.

California is located in one of the most seismically active areas of the earth. The explanation for this is that the state is located on the boundary between the plate underlying the Pacific Ocean and the one forming the American continent and the western North Atlantic Ocean floor. The Americas Plate, as the latter is called, is thought to be "drifting" southwesterly relative to the Pacific Plate and being forced to override the latter. The main line of contact between the two plates is the San Andreas fault system. Simply stated, as these plates shove and grind against one another, movement occurs on the San Andreas fault, or a fault parallel to it, and California has earthquakes.

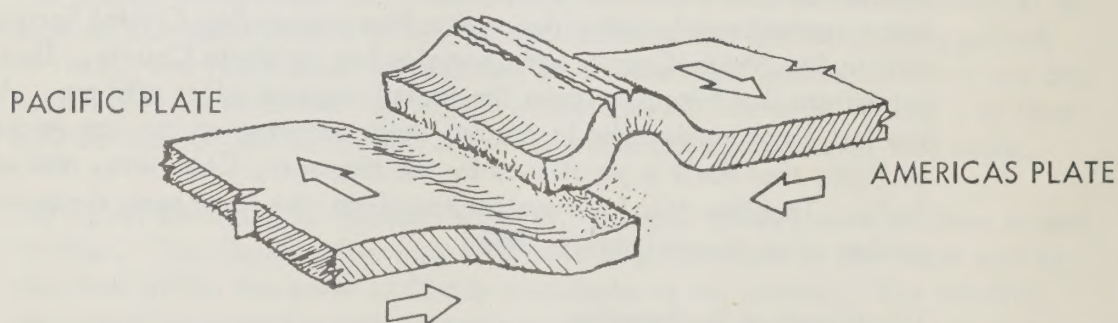
The San Andreas fault trends northwesterly through the Bay Area. The fault trace approximately coincides with a line connecting Crystal Springs Reservoir in San Mateo County with Tomales Bay in Marin County. Thus, in the immediate San Francisco area the fault is several miles offshore. Although the last great earthquake in the Bay Area occurred on the San Andreas fault in 1906, that fault is paralleled by the Hayward, Calaveras, and other major faults. Together this fault system has given rise to at least six severe earthquakes since approximately 1800.

The Effects of Earthquakes

Beginning the instant an earthquake is triggered, a series of events which can have serious consequences for property and people is set into motion. These involve interactions between seismic forces on one hand and natural features and man-made structures on the other.



A. The earth's "crust" is composed of several large "plates". These plates are slowly being pushed across the surface of the earth, away from the mid-ocean ridge systems. California is situated on the western edge of the Americas Plate, with the San Andreas fault forming the boundary between the Americas and Pacific Plates. The high seismicity of California is a direct result of its location on the edge of a plate.



B. As the Americas Plate is shoved westerly, away from the Mid-Atlantic Ridge, it over-rides the Pacific Plate. Because of its location on the western edge of the Americas Plate, California has been subject to earthquakes, faulting and folding as the two plates collide and grind against one another. Movement of the Pacific Plate, away from the East Pacific Rise, accounts for the lateral (strike-slip) movement on the San Andreas fault.

Source: Contra Costa County Planning Department Illustrations.

From the location along the earthquake fault where energy is released (the "focus"), force is radiated outward in the form of waves, which are only gradually dissipated. Near the focus, the forces may be strong enough to physically stress landforms and buildings, while at greater distances the waves can be detected only with instruments. The earthquake generates several types of waves. These waves travel at different speeds and arrive at places on the earth's surface at different times. These intervals recorded by instruments, allow earthquakes to be located.

As previously noted, the shear movement within the earth's crust that occurs during most California earthquakes may cause surface displacement along an existing fault or result in creation of new fault breaks. However, earthquakes that originate at great depths within the earth and earthquakes of Richter magnitude less than approximately 6.0 are generally not accompanied by surface faulting. Those earthquakes which are accompanied by surface fault movement pose a special hazard to structures which straddle the active trace. In the vast majority of damaging earthquakes, however, the preponderance of life loss and damage is a result of ground shaking and seismically-triggered ground failure.

Faults are seldom single cracks but typically are braids of breaks that comprise shatter zones. These link to form networks composed of major and minor faults. Movement typically occurs along the major faults, but a new path may be taken through a network, or a series of adjustments may occur on minor faults. A fault having recorded movement, or one which shows evidence of geologically recent displacement (within the last 11,000 years) is regarded as "active" and is more likely to generate a future earthquake than a fault which shows no signs of recent movement.

Although rock or ground rupture along a fault is dramatic, the physical effects of faulting are highly localized. Not so are the effects of ground shaking which are widespread and cause most earthquake damage. In a Great earthquake, major damage from ground shaking can occur over one hundred miles from the source of the earthquake.

The force which radiates outward from an earthquake is transmitted through the hard rock crust in short, rapid vibrations; these are transformed into long period, high amplitude motions when the waves enter soft ground materials. Sometimes, the undulations are long and deep enough to be visible as they move across the surface. These systematic differences in the characteristics of the ground motion can affect the design of sophisticated structures. More important from the standpoint of land use planning is that areas of thick,

water-saturated ground materials pose special engineering problems. Even special foundation engineering and drainage design efforts, however, may not always overcome the problems.

EARTHQUAKE MEASUREMENT

In addition to a common understanding of earthquake causes and effects, it is desirable for Seismic Safety Element users to have a common understanding of the terms used to describe earthquakes. This section, therefore, covers the measurement "scales" used in this document.

Earthquakes are typically described by their strength. The original way of classifying earthquakes is according to how they are felt and what effects are observed by people.

A currently-used version of such a system of rating "intensity" is the Modified Mercalli Scale which assigns Roman Numerals to earthquakes on a scale of I to XII. An earthquake of "M.M. I" intensity probably would not be sensed at all by most people, but one of "M.M. XII" would destroy most buildings and distort the landscape.

The modern systems measure earthquake size according to the "magnitude" of the energy release and express this amount on a mathematical scale. The Richter Scale, which expresses earthquake magnitude on a logarithmic scale, is the best known example of the latter.

Although most people evidently prefer to use the "language" of the instrumentally measured Richter Scale to the Modified Mercalli Scale's terminology of human perceptions in describing the strength of earthquakes, few understand the tremendous increases in energy releases which are being registered as readings move up the scale. Each Richter Scale unit increase in the scale (say, a change in reading from 1.0 to 2.0) means a ten-fold increase in the size of the wave transmitted by the earthquake or, roughly thirty-seven times the energy released by it. An earthquake measuring 3.0 on the Richter Scale would be roughly 1,000 times more powerful than one registering 1.0 (i.e., an increase of two full units on the scale).

A third measurement system that is as informal as the mathematical scales are precise is the use of descriptive titles for earthquakes of various strengths. According to this arrangement, earthquakes may be classified according to the names listed in Table 1.

TABLE 1 DESCRIPTIVE TITLES FOR EARTHQUAKES

Descriptive Title	Richter Magnitude	Intensity Effects
Micro earthquake	1 - 3.9	Only observed instrumentally or felt only near the epicenter. Modified Mercalli Scale, intensity IV or less.
Minor earthquake	4 - 5.9	Surface fault movement is not likely felt at distances of up to 20 miles from epicenter. May cause slight damage (Modified Mercalli Scale, VII) in small area.
Moderate earthquake	6 - 6.9	Severe earthquake range. Fault rupture probable; landslides triggered by shock waves; liquefaction and ground failure. Damage extends over a broad area, depending on magnitude and other factors. Maximum intensity ranges from VIII to XI on the Modified Mercalli Scale
Major earthquake	7 - 7.9	
Great earthquake	8 - 8+	

Compiled by Contra Costa County Planning Department

The overall strength of an earthquake is its most important characteristic but not the only characteristic needed to be known for seismic safety planning or construction design. Other important attributes include an earthquake's duration, its related number of significant stress cycles and its accelerations. Structures capable of withstanding more powerful earthquakes can fail in a less severe earthquake of long duration or one having especially high accelerations.

Earthquake characteristics are measured by instruments called seismographs. General purpose seismographs record stronger earthquakes occurring anywhere on the earth while microseismic instruments record events of usually 4.0 magnitude or smaller and for a localized area. Both types usually record continuously. In contrast, the strong motion seismograph (accelerograph) is inoperative until it is triggered by a strong earthquake. Histories compiled by seismo-

graphs are necessary to evaluate the risk to an area according to the number and strengths of future earthquakes. Information on large and small earthquakes is also critical in locating potentially active faults, although earthquake epicenter information is generally considered to be less certain evidence of activity than proven fault offset of Holocene or Quaternary deposits.

PUBLIC RESPONSE TO SEISMICITY

Mankind has the capability, through wise building and land development practices and land use planning--taking into account the materials and forces of the earth itself--to minimize the destructiveness of even the most severe earthquakes.

In an area of high seismicity, planning, development, and building should incorporate scientific and engineering knowledge of earthquake causes and the response of ground and structures to earthquake forces.

All levels of government responsible for guiding and regulating development and building in seismically active areas should adopt plans, policies and procedures, and enact legislation, to ensure the application of scientific and engineering knowledge to the protection of lives and property.

LOCAL SEISMICITY

INTRODUCTION

The previous chapter discussed seismicity as a geologic process. It showed that earthquakes are natural phenomena caused by worldwide geologic forces that are forming the earth's continents and ocean basins. It provided a context for explaining seismic activity in Contra Costa County and the Bay Area.

The plate tectonic theory provides a comprehensive explanation for the mountain building, volcanism and earthquakes which have characterized the geologic history of the Bay Area. According to this theory the major terrain features of Contra Costa County owe their origin to the same geologic forces that generate earthquakes and produce earthquake faults. They have operated for millions of years, and there is no reason to believe that the forces will cease to change the County's landscape in the future.

Less dramatically, the County's landscape is being altered by the natural processes of erosion and deposition (which are affected by local climate and vegetation) as well as by man. The resulting ground materials and landforms are more or less susceptible to seismic activity. Some, such as the slip-prone hill soils and the water-saturated sediments of interior valleys and shoreline plains, are highly vulnerable.

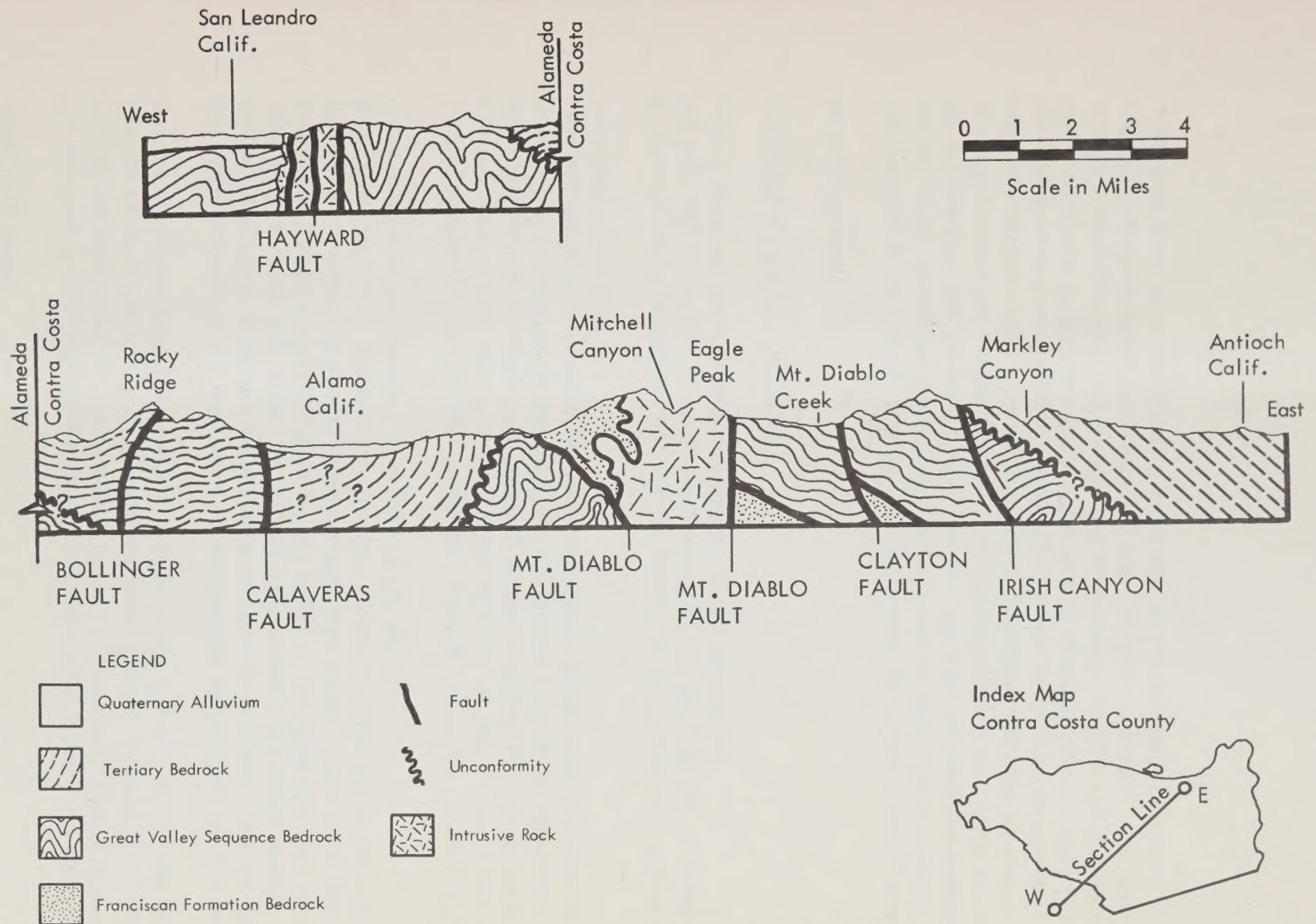
By knowing what geological hazards are present in the County and where these are located, better public and private decisions can be made on the appropriate uses of land and the standards of construction for buildings.

GENERAL COUNTY GEOLOGY

Bedrock Geology

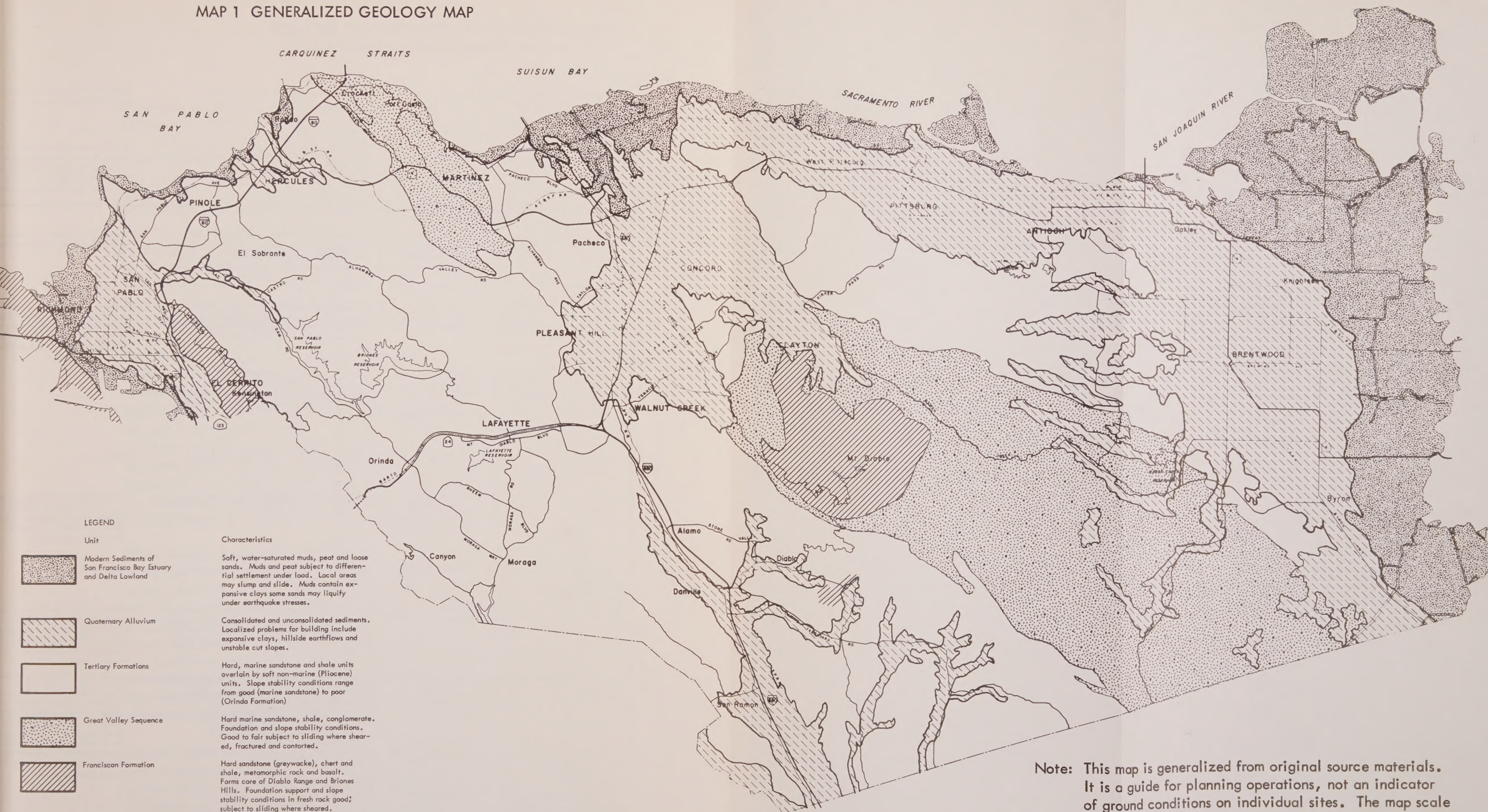
The geology of the County is dominated by several northwest trending fault systems which divide the County into large blocks of rock. For example, the Briones Hills are bounded by the Hayward fault on the west and elements of the Calaveras fault system on the east. Within a particular block the rock sequence consists of (1) a basement complex of broken and jumbled sedimentary, igneous and metamorphic rocks; (2) a section of younger sedimentary rocks more than 35,000 feet thick; (3) volcanic rocks (flows and tuffs) which locally intertongue with and overlie the sedimentary section; and (4) surficial deposits including slides, alluvial fans, and Bay Plain deposits. The character of each of these four categories of rocks may be summarized as follows.

FIGURE 2 GEOLOGIC SECTION THROUGH CONTRA COSTA COUNTY



Contra Costa County Planning Department Illustration

MAP 1 GENERALIZED GEOLOGY MAP



Source: Compiled from mapping of the U.S. Geological Survey and California Division of Mines and Geology

Prepared by Contra Costa County Planning Department, December 1975

Contra Costa County, California

TABLE 2 GENERALIZED STRATIGRAPHIC SECTION AND ENGINEERING CHARACTERISTICS

GENERALIZED STRATIGRAPHIC SECTION Geologic Age (Absolute Age*)			GENERAL LITHOLOGIC DESCRIPTION	REMARKS (includes slope stability, earthquake stability, etc.)
CENOZOIC ERA	QUATERNARY			
	Holocene & Pleistocene	Alluvium	Includes all types of alluvial deposits. In central Coast Range it is separated from Contra Costa Group by an angular unconformity.	Loose, water-saturated deposits possess many adverse engineering characteristics including low seismic stability, questionable bearing strength; granular material may have high liquefaction potential.
	TERTIARY			
	Pliocene (1-11)	Contra Costa Group	Bald Peak Basalt Siesta Formation Moraga Formation Orinda Formation	Slope stability poor. Abundant slides both soil and rock, on natural and cut slopes.
			Conglomerate, sandstone, siltstone with minor amounts of limestone and tuff, rapid facies changes. Some basalt and andesite (volcanic) flows. Clastics are semi-consolidated and contain montmorillonite clay. Topographic form highly variable.	
	Miocene (11-25)	San Pablo Group (Diablo Range)	Neroly Sandstone Cierbo Sandstone Briones Sandstone	Slope stability condition moderate to good. Generally stands in 1:1 cuts with minor sloughing. Locally forms slopes so steep that development may be difficult. For limitation, see discussion of Franciscan formation.
			Predominantly marine sandstone, with interbeds of shale, siltstone and minor conglomerate. Upper part includes some non-marine beds (e.g. Diablo Formation of Weaver, 1944)	
		Monterey Group (Briones Hills)	Rodeo Shale Hambra Sandstone Tica Shale Claremont Shale Sobrante Sandstone	See above.
			Siliceous shale and fine-grained sandstone. Some zones of rhythmically bedded chert and shale. Bituminous in places. Underlies moderately steep to steep hillsides in Briones Hills.	
	Oligocene (25-40)		San Ramon Formation	See above.
			Tuffaceous sandstone, tuff, minor conglomerate and siltstone.	
	Eocene (40-60)		Markley Formation Nortonville Shale Domengene Sandstone Meganos Formation	Slope stability generally good; stands in 1:1 slopes with minor sloughing. Foundation conditions vary with material. For limitations see discussion of Franciscan formation.
			Predominantly indurated bedrock, including shale, siltstone and sandstone.	
	Paleocene (60-70)		Martinez Formation	See above.
			Marine, glauconite sandstone, siltstone and shale.	
MESOZOIC ERA	CRETACEOUS			
			Great Valley Sequence	Slope stability and foundation conditions vary with material, but generally good to fair unless sheared or weathered. For limitations, see discussion of Franciscan formation below. Earthquake stability high.
			Great Valley Sequence: Massive beds of sandstone alternating with siltstone and shale. Minor conglomerate, limestone and lignite. Complexly folded and faulted. Outcrops in Briones Hills and Diablo Range.	
	CRETACEOUS-JURASSIC		Franciscan Formation	Slope stability and foundation conditions in fresh rock generally good. Limitations subject to landsliding where intensely sheared or weathered; dip slopes hazardous--should be cut at lower angle than dip of beds. Earthquake stability high (i.e. hard bedrock such as Franciscan tends to attenuate earthquake waves, reducing ground motion).
			Franciscan: Rhythmically bedded graywacke sandstones, shale, siltstones, radiolarian chert, greenstone. Minor amounts of limestone and schist. Partially recrystallized and intruded by serpentine and associated igneous rocks. Strongly deformed.	

*Units of absolute age are millions of years before present.

Modified after Radbruch (1969)

NOTE: This table is generalized from original source materials. It is a guide for planning operations, not an indicator of ground conditions on individual sites.

Compiled by Contra Costa County Planning Department

Basement Complex. The oldest bedrock on the surface in the County is the strata of the "Franciscan Formation". It is thought that this group originated on the Pacific floor and was "welded" to the western margin of the American continent by plate movement. Subsequently it was pushed upward through younger sedimentary rock to form the backbone of the Diablo Range. Isolated outcrops also appear in some other portions of the County. Befitting this history, the rock strata of this formation are highly distorted and its layers of sedimentary rock are partially metamorphosed through heat and compression. It is intruded by a rock called serpentine as well as other (volcanic) rocks which originated in the earth's molten core. The relative hardness of the rocks in this formation gives them good overall behavioral characteristics during earthquakes. But, it is associated with rough topography, and the weathered or sheared materials of some of its steep slopes may be susceptible to landsliding.

Sedimentary Rocks. The next oldest bedrock formation in the County is the so-called "Great Valley Sequence". These are sedimentary rocks laid down under ancient seas that once existed on the American continent. Its strata have been folded but less extremely than those of the Franciscan Formation, and the layers are not as highly altered as the Franciscan. Still, the rock tends to be hard and behave well during earthquakes. The slope stability characteristics of these rocks span a wide range. Erosionally oversteepened slopes, and slopes underlain by sheared or weathered material are subject to sliding. Great Valley Sequence rocks outcrop at higher elevations in the central portion of the Diablo Range and east of the Franklin fault in the Briones Hills.

The youngest thoroughly consolidated ("hard") bedrock in the County is the group laid down during the geologic age known as the "Tertiary". These strata of largely sedimentary rocks have been folded like their predecessors, but because they have not been as hardened by geologic processes their responses to earthquakes are much more variable. Certain of the constituent groups of rocks, such as the Orinda Formation, tend to be weak and highly susceptible to landslides. It is expected that these weaker areas would experience numerous instances of ground failure during strong earthquakes. Significantly, many of the foothill areas of the County now coming under development are underlain by Tertiary age bedrock.

Volcanic Rocks. Volcanic flows and tuffs as young as Pleistocene age, outcrop at scattered localities in the central Coast Ranges of California. In Contra Costa County, the Leona rhyolite is exposed in the Berkeley Hills of El Cerrito; basaltic flows and tuffs are present in Orinda Formation equivalents, west of the Moraga fault; and basaltic flows which are overlain by recent gravels are exposed in the Diablo Range three miles northwest of Clayton.

Surficial Deposits. These units, which vary widely in their origin and engineering properties, overlie bedrock formations in some areas. In the mountainous portions of the County the surficial deposits include slides, alluvial fans, travertine (lime) and upland valley bottom deposits. In the lower-lying portions of the County the surficial deposits include Bay Plain sediments and the geologically recent deposits of the San Francisco Bay estuary and Delta lowland. From the perspective of seismic safety planning the older, coarser, and well-drained materials tend to be stable during earthquakes, while younger, fine-grained and water-saturated deposits tend to be less stable.

Planning Implications

In areas of substantial risk, geologic conditions should be a primary determinant of land use. Generally, urban or suburban uses or intensities should not be planned for areas where geologic conditions would result in unacceptable risks to life and safety, and areas where the public costs of overcoming geologic deficiencies would exceed public benefits. It should be recognized, however, that much can be done to mitigate potentially hazardous conditions. Project approvals in areas of substantial risk should be based on knowledge of local ground conditions.

Because it is impractical for government to prepare geologic information at great detail on a Countywide basis, it is preferable to deal with geologic conditions through "project review" requirements rather than to make them parts of ordinances. Policies and regulations requiring studies should be flexible, providing for the exercise of professional judgment. Depending on circumstances the requirement for geologic and/or soils investigations could be phased or staged, with an initial requirement for a reconnaissance report to be followed by a geologic hazards report or a preliminary soils report, where appropriate. The purpose of the reconnaissance report is to identify areas requiring special management and to recommend an exploration program to define and delineate any geologic hazard or potentially hazardous soil condition. The purpose of the second stage studies, where needed, are to accurately identify developable areas and to recommend means of mitigating potentially hazardous conditions.

The Contra Costa County Planning Department should compile an administrative map primarily for project review operations, based on the mapping of the U.S. Geological Survey, California Division of Mines and Geology, and reports prepared for development projects. As such the proposed administrative map will summarize the findings of government agencies and private consultants. Geologic formations should be classified according to their characteristics for land use capability. Available geology mapping can be used until this map is prepared.

LOCAL EARTHQUAKE FAULTS

Characteristics and Classification

Earthquake faults were described earlier as bedrock joints or cracks made by movements to relieve stress in the earth's crust. The likelihood is that future movements--accompanied by earthquakes--will occur on existing breaks, but even dormant faults (by altering natural drainage and other phenomena) affect natural features and man-made development over them. All faults are important, then, even though it is obvious that those with the more evident potentials for movement warrant more consideration than those likely to remain dormant.

Faults vary in importance, but there is no really satisfactory classification. Faults dividing large parts of the earth, such as the San Andreas fault separating the Pacific Ocean floor from the American Continent, are normally of greatest importance, but strain accumulated by plate movement may be relieved by movements of major subsidiary faults (such as the Hayward or Calaveras) which are important regionally, or by lesser faults (such as the Concord) which are important locally. All of these probably are interconnected--if not physically, then by strain patterns. This is to say that they are, from a local perspective, all parts of a grand system.

The amount of energy that a fault can accumulate and release seems, within limits, to depend on its length. Therefore, only the longer faults, such as the San Andreas, Hayward or Calaveras, appear to be capable (by application of this rule) of generating Great or Major earthquakes. But, some experts fear that several lesser faults could "link" to jointly produce more powerful earthquakes.

Another way of classifying faults is by their activity, a method that assumes that faults which have moved in the recent past are those that have the highest probability of moving again in the future. The principle is reasonable provided the exceptions and evidence are understood.

Faults Showing Activity

Faults in Contra Costa County that have shown signs of activity include the Hayward and Calaveras faults which have been the source of severe earthquakes in historic time that were accompanied by surface faulting. Other faults, such as the Antioch, Concord, and Pleasanton faults are considered to be active by the U.S. Geological Survey because they exhibit features which have been interpreted as evidence of tectonic creep.

With regard to public safety, the most critical fault in the County is the Hayward fault which passes through several West County communities. Currently, it is creeping in several locations and it was the source of severe earthquakes in 1836 and 1868.

Because of the relatively small population that existed in the Bay Area in the nineteenth century, the damage potential of past earthquakes was somewhat limited. The cities of Concord and Antioch have sustained damage from earthquakes in 1955 and 1965, respectively. There was no evidence of surface faulting accompanying these earthquakes. However, the location of the epicenter of the main event and aftershocks show a good agreement with the mapped trace of the Concord and Antioch faults.

Other Local Faults

In addition to the faults which have been classified as active, there are others in the County whose activity status has not been clearly established by presently available information.

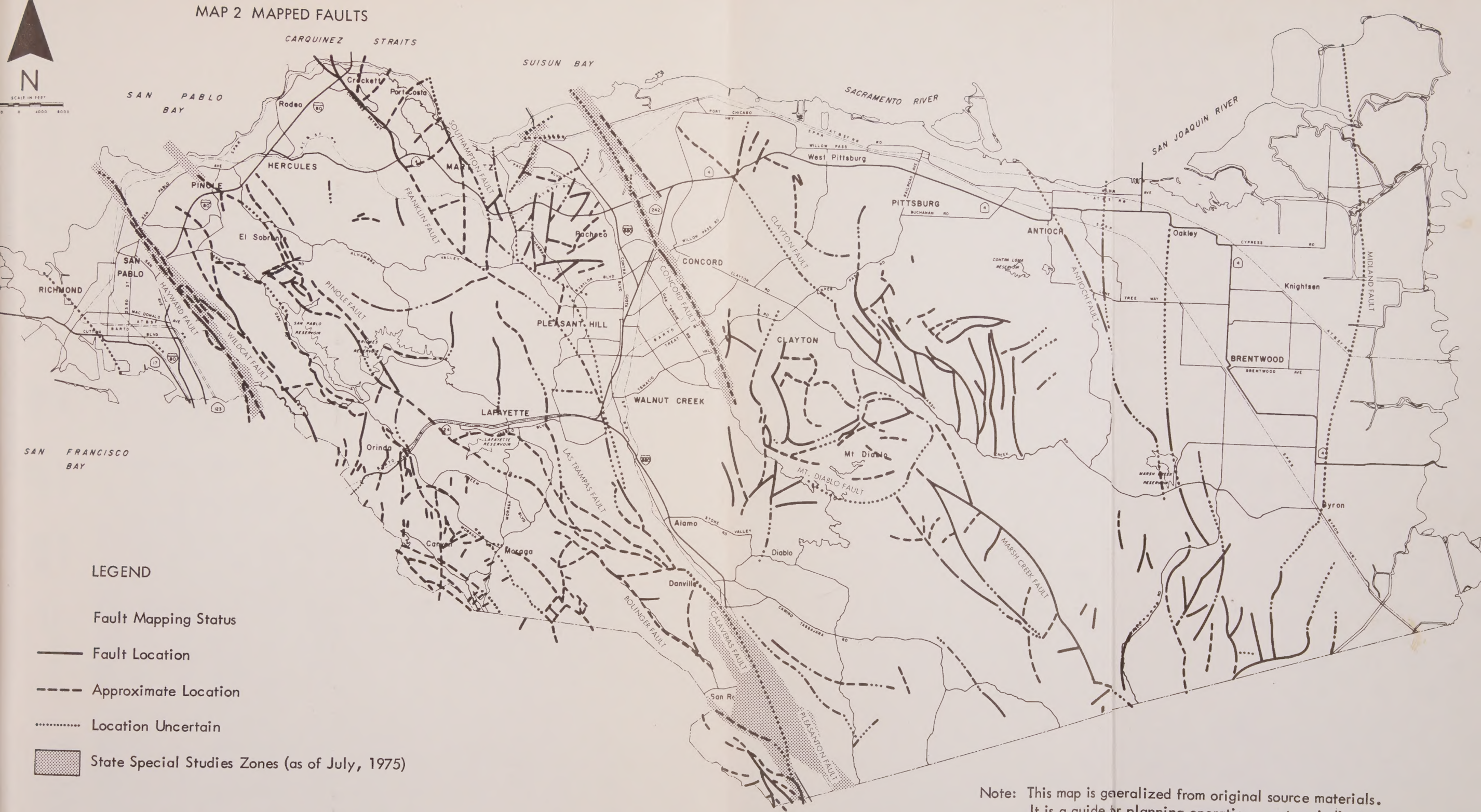
The prominent faults of undetermined status include the Pinole, Bolinger, Las Trampas, Franklin, Southampton, Clayton-Marsh Creek, Midland, and Mt. Diablo faults. Similarly, there is a system of radial and concentric faults surrounding Mt. Diablo which are not known to be active but which were created by the mountain's uplift through younger rocks--a process which is still occurring.

Detailed geologic maps show numerous minor faults throughout Contra Costa County. Few are likely to be active (or capable of generating an earthquake) but they need to be located and studied in the course of developing land.

Alquist-Priolo Special Studies Zones Act

The Alquist-Priolo Special Studies Zones Act charged the State Geologist with responsibility for preparing maps delineating Special Studies Zones of appropriate width to include all potentially and recently active traces of the San Andreas, Hayward, Calaveras and San Jacinto faults, and it made provision for the State Geologist to zone other faults where the available evidence was adequate. Within Contra Costa County, the faults which were zoned in the initial phase of the mapping included the Hayward fault, an unnamed fault in the Pinole area, unnamed faults in the Martinez area, the Concord fault, a segment of the Calaveras fault and the Pleasanton fault. The enabling legislation also charged the State Mining and Geology Board with responsibility for formulating policies and criteria affecting all development applications which come under the authority of the Alquist-Priolo act. The enabling legislation specifies that policies and criteria of the Board be embodied in the policies and

MAP 2 MAPPED FAULTS



Source: Fault information compiled from U.S. Geological Survey Materials.
Special Studies Zones are from official maps of the State Geologist.

TABLE 3 SUMMARY OF AVAILABLE DATA ON THE ACTIVITY STATUS OF MAJOR FAULTS IN CONTRA COSTA COUNTY

FAULT	HISTORIC DAMAGING EARTHQUAKES	SURFACE FAULTING (INCLUDES TECTONIC CREEP)	CURRENT MICROSEISMIC ACTIVITY	PROVEN HOLOCENE DISPLACEMENT	PROVEN QUATERNARY DISPLACEMENT	REMARKS	REFERENCES
ANTIOCH	1872? 1965	Creep Reported	Seismically Active Zone	Reported Displacement	Reported Displacement	Reported evidence of tectonic creep.	McEvilly (1967), Bolt (1971), Burke (1973) Burkland (Geol. Investigations for Sube 4320, 4510; M.S. 4-74, 5-74), Levish (Personal Communication).
CALAVERAS	1861	Yes	Yes	Yes	Yes	Currently exhibit tectonic creep near Heilster. Evidence of Holocene displacement near Dublin. Fault shows right lateral offset.	Radbruch (1968), Rodgers and Nason (1968), Brown (1970), Greensfelder (1973), Burkland (Geol. Investigation for Sub 4699).
BOLINGER	None Known	None Known	No	None Known	None Known	Displacement and movement history are largely unknown. Activity status uncertain.	Ham (1952), U.S.G.S. (Unpublished).
LAS TRAMPAS	None Known	None Known	No	None Known	None Known	Displacement and movement history are largely unknown. Activity status uncertain.	Lawson (1914), Ham (1952), Saul (1973).
FRANKLIN	1898?	None Known	No	None Known	None Known	Believed to be main trace of Calaveras system in north half of County. Sketchy epicenter data suggest possible relationship to Mare Island earthquake.	Talmon (1931), Radbruch (1967), Saul (1973), Sims (1973).
SOUTHAMPTON	None Known	None Known	No	None Known	None Known	In Martinez area two faults which intersect or are branches of the Southampton fault have been included in State Special Study Zones.	Talmon (1931), Sims (1973), Cooper-Clark (1974, Geol. Investigation for County Detention Facility).
CLAYTON-MARSH CREEK	Epicenter Data Sketchy	None Known	No	None Known	None Known	Photo lineation crosses geologically young landslide deposits in Clayton area. Position and orientation of fault suggests possible relationship to the active Green Valley fault.	Talmon (1931), Brabb (1971), Woodward-Lundgren (1974, Geol. Investigation for Keller Ranch, Clayton).
CONCORD	1955	Yes	Yes	Yes	Yes	Locally, exhibits evidence of periodic tectonic creep. Right-lateral offset.	Poland (1935), Sharp (1973), Sims (1973), Burkland (1973, Geol. Investigation for Buchanan Oakes), Berloger (1974, Geol. Investigation for Lehmer Oldsmobile property).
HAYWARD	1836, 1868	Yes	Yes	Yes	Yes	Locally, fault exhibits evidence of periodic recent tectonic creep. Right-lateral offset.	Radbruch (1968), Brown (1970), Nason (1971), Bishop (1973).
WILDCAT	None Known	Yes	Available Data Inconclusive	Yes	Yes	Exhibits evidence of creep near Contra Costa College.	Bishop (1973).
MIDLAND	1892?	None Known	Outside NGER Network	None Known	None Known	Epicenter area of 1892 earthquake approximately coincides with mapped trace of Midland fault.	Brabb (1971), Greensfelder (1973).
MT. DIABLO	None Known	None Known	Available Data Inconclusive	None Known	None Known	Movement history of Mt. Diablo fault unknown. Evidence of active faulting on radial and concentric faults on flanks of Mt. Diablo.	Brabb (1971), Levish (1974, personal communication), Harding, Lawson (Geol. investigation for 1878-R2).
PINOLE	None Known	None Known	Available Data Inconclusive	None Known	None Known	Mapping of Weaver (1949) and Sims (1973) suggests that fault may disturb Quaternary deposits. Possible relationship to active Healdsburg-Rodgers Creek fault.	Weaver (1949), Radbruch (1967), Sims (1973).
PLEASANTON	None Known	Suggestive	Yes	Yes	Yes	Locally exhibits evidence of tectonic creep. Most recent movement appears to be area east of fault uplifted relative to west. Evidence of strike-slip displacement inconclusive.	Radbruch (1968), Brown (1970), Burkland (1973, Geol. Investigation for 1808-R2), Terrasearch (1974, Geol. Investigation for Sub. 4650).

NOTE: This table is generalized from original source materials. It is a guide for planning operations, not an indicator of ground conditions on individual sites.

and development regulations of affected local jurisdictions. The State is presently reviewing the Antioch fault for placement in a Special Studies Zone.

The Alquist-Priolo act requires cities and counties to exercise specified approval authority with respect to new real estate development and most types of new construction within the Special Studies Zones. Specific policies and criteria to assist local jurisdictions are provided by the State Mining and Geology Board. Other requirements and guidelines are provided by the Alquist-Priolo act.

The Alquist-Priolo act does not pertain to existing development, or to the construction of wood-frame, single family homes on existing lots. The act also exempts certain alterations or additions to existing structure. To date the Alquist-Priolo act has been administered as a matter of Board of Supervisors' policy. But, the County has gained experience in administering this law, and it appears feasible and desirable to incorporate these regulations into an ordinance.

Planning Implications

All faults, to varying degrees, should be given consideration in the design of developments and in site preparation. For example, it should be recognized that many minor, presumed inactive faults in the County intersect active or potentially active faults. It is conceivable that movement on the master fault could trigger adjustments on minor cross faults or adjacent sub-parallel faults. It should also be noted that the engineering character of the crushed material in the fault zone may affect foundation and drainage design.

Structures intended for human occupancy must not be erected over an "active" fault trace. However, even inactive faults should be given consideration in the review of proposed projects.

To the extent practicable, structures which affect the provision of needed services (e.g., highway interchanges, utilities) should not be erected over the trace of an active or potentially active fault. Where it is deemed essential to do so for the public welfare, these structures should be designed to accommodate or minimize the effects of fault displacement and seismically-triggered ground failure.

Land in the setback areas along active and potentially active fault traces should be utilized for open forms of land use that could experience displacement without endangering large numbers of people or create secondary

hazards. Examples are yards, greenbelts, parking lots, and non-critical storage areas. Roads, particularly those which carry large volumes of traffic, should be sited over active faults only where other alternatives are impractical.

The geologic investigation required for subdivisions and planned unit developments should consider faults in the vicinity of the site. Because of the relatively greater significance of the fault systems listed in Table 3 they should receive special consideration in the report.

Contra Costa County, through its Planning Department, should compile a "fault map" for use in the administration of project reviews (e.g., Environmental Impact Reports and mandatory referrals) and in the administration of development ordinances. Preferably, this map should be on a countywide basis and in the form of a map series at a scale of 1:24,000 (1" = 2000') to make efficient use of U.S. Geological Survey, Division of Mines and Geology fault information, University studies and the results of consultant reports. The generalized fault map can be used until this more detailed map is available.

EARTHQUAKES--PAST AND FUTURE

Earthquake History

Every earthquake, great or small, is important to the area where it is felt. Each earthquake helps locate active faults and establish probability patterns for projecting future earthquakes.

The written history of Contra Costa County indicates that it has experienced frequent earthquakes. Early explorers and settlers in the Bay Area told of earthquakes that must have been felt in Contra Costa County, but the continuous history that has been maintained since the early 1800's clearly shows that the County has been subject to numerous seismic events. To show the pervasiveness of seismic events in this region, one authority has estimated that there have been approximately sixty damaging earthquakes in the Bay Area since 1800. Almost all of these were felt in Contra Costa County, and some did extensive damage here. Some of these originated on faults located within the County and some in other parts of the region.

There is no question that the six major Bay Area earthquakes occurring since 1800 affected the County: the 1836 earthquake produced a fissure along the Hayward fault in western county from San Pablo far into Alameda County; the

1861 earthquake on the Calaveras fault broke the surface for eight miles through San Ramon Valley; the 1868 earthquake on the Hayward fault damaged the Courthouse in Martinez; and the 1906 San Francisco earthquake on the San Andreas fault caused widespread damage here. Fortunately the County did not bear the main brunt of the San Francisco quake but two earlier Nineteenth Century major earthquakes were certainly destructive here.

Two of the three fault systems that produced these six major earthquakes pass through Contra Costa County.

Interestingly, these six major Bay Area earthquakes happened in the seventy year period ending in 1906, while none has occurred in the comparable period since then. Experts do not yet know if the 1906 earthquake released so much strain that there will be no major earthquakes for awhile or if the Bay Area fault systems have been accumulating energy for most of the Twentieth Century. To some, the absence of some slippage along the San Andreas fault in the upper Bay Area indicates that energy is being stored.

The lack of a long period of written history here is a hindrance to understanding possible earthquake "cycles". (In some parts of the world, the seismic history goes back more than a thousand years.)

Although lesser earthquakes in Contra Costa County have been sporatically reported for more than a century, the County has been systematically monitored by general purpose seismographs only since 1934 (and only since 1970 by small motion seismographs). The general purpose instruments of the University of California have recorded nearly 600 earthquakes with intensity readings of 2.0, or greater, on the Richter Scale during the ensuing (and relatively quiet) forty year period.

The generalized distribution of these earthquake epicenters is arrayed on Figure 3, which shows the surface locations of major faults for relationship.

Some of the difference between epicenter and fault locations are due to inexact locational or mapping technology; other differences reflect the slanting of the fault break through the bedrock; but, still other differences may indicate that lesser earthquakes are taking place on minor faults, or on undiscovered active faults, in the County.

Seismic Activity in Western, Central, and Eastern Contra Costa County

Western Contra Costa County has experienced severe levels of ground shaking during moderate to great earthquakes on the San Andreas (1838, 1865, 1906) and Hayward faults (1836, 1868) as well as earthquakes on unknown faults, such as the Mare Island earthquake of 1898. These seismic events have resulted in ground shaking intensities ranging as high as X (very severe) on the Modified Mercalli Scale.

During the past forty years approximately one hundred earthquakes have been recorded which have epicenters in western Contra Costa County or adjacent Alameda County. Although no fault rupture has accompanied any of these earthquakes, it is reasonable to attribute most of these seismic events to the Hayward fault. During this period, the largest earthquake to be recorded had a magnitude of 4.5 on the Richter Scale.

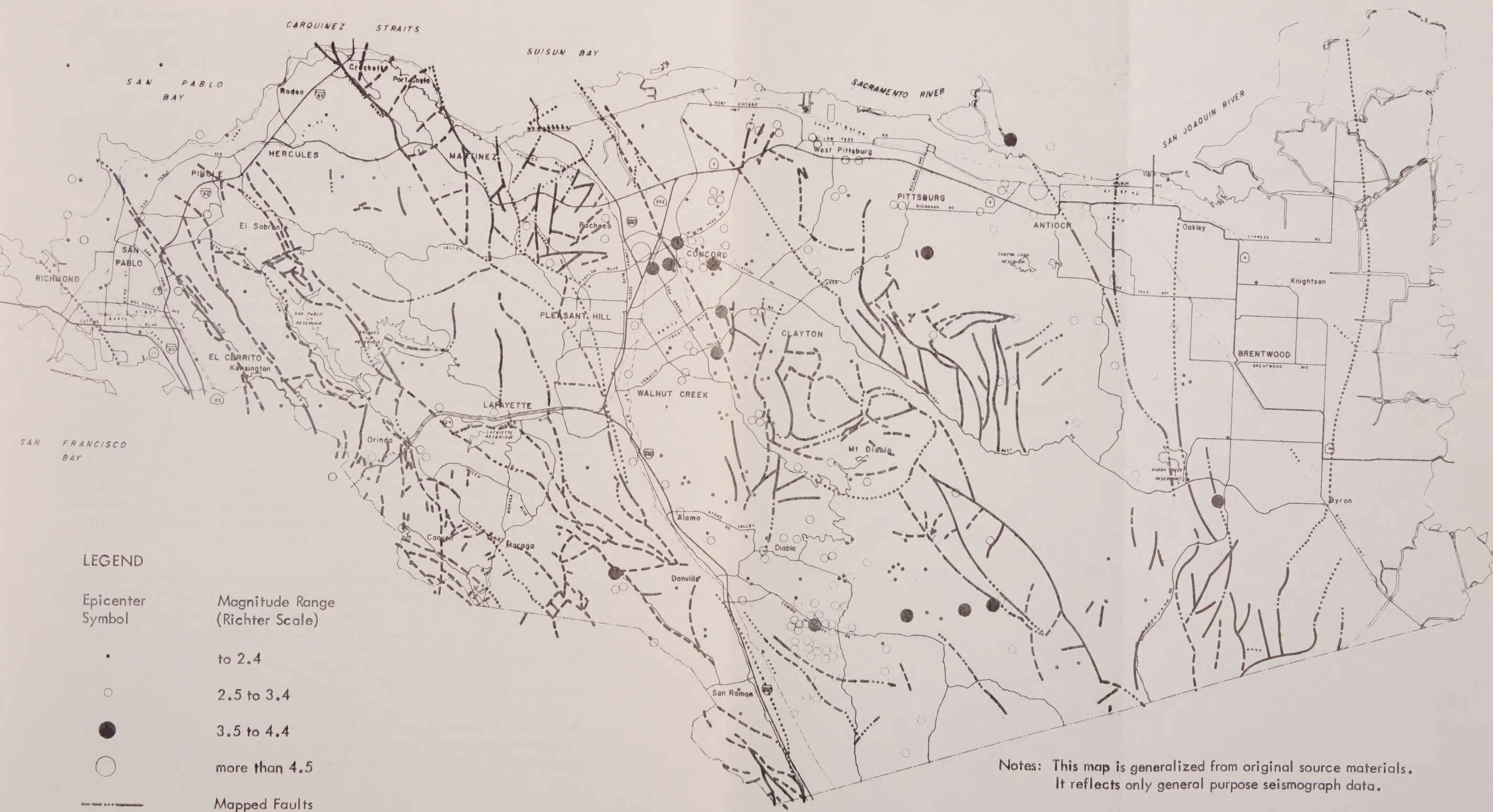
Microseismic data, which is available only for the year 1970 through September 1973, shows a marked concentration of small earthquakes along the mapped trace of the Hayward fault. Additionally, numerous widely scattered microseismic epicenters have been plotted in the Briones Hills. Systematic interpretation is not possible at present but as the number of recorded earthquakes continues to increase it may prove feasible to assess the seismicity of the several mapped bedrock faults which bisect the hills.

Within the central portion of Contra Costa County (which includes the Diablo-San Ramon Valley and the adjacent flanks of the Briones Hills and Diablo Range) are two known active fault zones and several other faults of uncertain activity.

During historic time the largest earthquake to originate in the central portion of the County is the July 2, 1861 earthquake on the Calaveras fault. This event, which produced ground shaking rated as IX on the Modified Mercalli Scale in the Livermore area, reportedly produced a fissure eight miles long on the west side of San Ramon Valley in southernmost Contra Costa County and adjacent Alameda County. The central portion of the County has also experienced damage to structures, and landslides have been triggered by earthquakes on the Hayward and San Andreas faults, as well as from earthquakes on unknown faults. The maximum levels of ground shaking from these events is known or inferred to have reached VIII on the Modified Mercalli Scale.

Since 1934 nearly two hundred earthquakes have been recorded in central Contra Costa County by general purpose seismographs. Ten of these earthquakes have had magnitudes ranging from 4.0 to 5.4. Although none of

FIGURE 3 EARTHQUAKE LOCATIONS, 1934-1971



Notes: This map is generalized from original source materials. It reflects only general purpose seismograph data.

The apparent scattering of the epicenters relative to fault locations is due to instrumentation and measurement problems as well as the dip of the faults and other factors.

Source: Compiled by the Contra Costa County Planning Department from University of California (Berkeley) Seismograph Station Records.

these events has been assigned to an earthquake fault, the location of the epicenters suggest these earthquakes may be related to movements occurring at depth on the Concord, Pleasanton and Livermore faults. The largest earthquake during this period of time was the October 12, 1955 Concord earthquake of magnitude 5.4.

Another notable seismic event is the 1970 earthquake swarm in the San Ramon Valley, east of Danville, which consisted of several hundred small-magnitude earthquakes. The significance of these earthquakes is not established by existing data. It is pertinent to note that no mapped fault passes through the epicentral area.

Historically, eastern Contra Costa County has been subject to relatively severe levels of ground shaking. One authority states that the areas adjacent to Carquinez Strait-Suisun Bay exhibited the highest levels of seismicity in central California prior to 1906. Within a forty-five year period, between July 1861 and April 1906, at least ten damaging earthquakes produced strong ground motion in eastern Contra Costa County. Seven of these shocks are known or inferred to have produced maximum ground shaking of intensity VIII on the Modified Mercalli Scale.

Of the many seismic events which produced strong ground motion in eastern Contra Costa County, two merit special mention. A severe earthquake in 1872 was centered in the Antioch area, where Modified Mercalli intensities reached IX or X. It appears reasonable to conclude that the earthquake emanated from the Antioch fault. A severe earthquake in 1892 was centered east of Fairfield. Significant damage occurred in Winters, Dixon, Vacaville and Suisun, and some damage was done as far away as Sacramento and Martinez. Although the fault responsible for these earthquakes is unknown, the only major fault in the epicentral area is the Midland fault.

Since 1934 general purpose seismographs have recorded numerous small-magnitude earthquakes (less than magnitude 4.0) in eastern Contra Costa County, but none of these events have been assigned to mapped faults. The largest earthquake to have an epicenter in this portion of the County is the 1965 Antioch earthquake of magnitude 4.9.

Earthquake Probability

Man does not possess the capability to predict when, where, or how large the next earthquake will be. However, the "state-of-the-art" is rapidly advancing and consequently, our ability to predict the geographic location

and timing of earthquakes can be expected to improve dramatically during the next decade.

Several estimates of earthquake probability for the Bay Area have been made by scientific organizations, and their results are roughly comparable. A representative forecast by the National Oceanographic and Atmospheric Administration anticipated that the average return period was seventeen years for a 6.0 magnitude earthquake, thirty-two years for a 7.0 event, and one hundred seventy years for an 8.3 event.* Based on these figures, one would expect a moderately damaging earthquake on the average of every seventeen years ($\pm$), a severely damaging earthquake (local disaster) on the average of once every thirty-two years, and a Great earthquake (regional disaster) on the average of every one hundred seventy years. Any of these forecasts, of course, depend on the limited earthquake frequency information available here from a relatively short period of written history.

Using the available data and information, an earthquake probability estimate has been developed for Contra Costa County. It evaluates the likelihood that earthquakes capable of producing damage in Contra Costa County will occur on certain faults during a fifty year period. (Fifty years is a rough average nominal life of a structure.) The forecast shows that a structure built in Contra Costa County is likely to be subjected to a severely damaging earthquake during its useful life, and it shows that the earthquake could originate in several locations.

*Algermissen, S.T., et al. (1972) "Study of Earthquake Losses in the San Francisco Bay Region", Report prepared for the Federal Office of Emergency Preparedness by N.O.A.A., 220 p.

TABLE 4 APPROXIMATE PROBABILITY OF OCCURRENCE OF
EARTHQUAKES ON SELECTED BAY AREA FAULTS
(50-Year Period)

<u>Causative Fault</u>	<u>Magnitude</u>	<u>Approximate probability of Occurrence (over a 50-year period)</u>
San Andreas	7.0 - 8.0	Likely
	8.0 - 8.5	Intermediate
Hayward-Wildcat	6.0 - 7.0	Likely
	7.0 - 7.5	Intermediate
Calaveras	6.0 - 7.0	Intermediate
	7.0 - 7.5	Intermediate - Low
Concord	5.0 - 6.0	Likely
	6.0 - 7.0	Intermediate - Low

LIKELY: Greater than 50% probability of occurrence

INTERMEDIATE: 15 - 50% probability of occurrence

LOW: Less than 15% probability of occurrence

Source: Contra Costa County Planning Department Estimates

Earthquake Parameters

Knowing that a structure probably will be subject to a damaging earthquake during its useful life, it is only reasonable that it be designed to survive the event, or to at least protect its occupants and functions. To do this, architects and engineers need to have information on earthquake characteristics, such as earthquake accelerations and duration of strong ground shaking. These characteristics have been estimated for selected faults. The resulting table (Table 5) may be used as an approximation of parameters prevailing over a large area and as a beginning point for determining the parameters affecting a particular location.

The earthquake parameters are not intended to be used as requirements for public and private projects, but they should be used only by qualified personnel in project background evaluations, and by engineers and architects in their development of structural design criteria. (Prediction of ground motion on a particular building site requires site-specific knowledge of ground conditions and an assessment of the effect of local geology in changing the characteristics of ground motion.)

TABLE 5 ESTIMATED MAXIMUM PARAMETERS FOR KNOWN FAULTS
AFFECTING CONTRA COSTA COUNTY

	San Andreas Fault	Hayward and Calaveras Faults	Concord and Green Valley Faults
Estimated Magnitude ¹ (Richter Scale)	7 to 8.25	6 to 7.5	6 to 7
Estimated Fault Offset ² (feet)	4 to 30	1 to 8	1 to 4
Estimated Duration Strong Shaking ³ (seconds)	24 to 37	5 to 30	5 to 24
Estimated Length of Tectonic Rupture ⁴ (miles)	40 to 300	5 to 70	5 to 25
Estimated Maximum Intensity ⁵ (M.M.)	VII to VIII	IX to X	VIII to IX
Estimated Peak Horizontal Accelerations in Bedrock ⁶ (g's)			
Distance from Causative Fault	at 5 miles	over .50	over .35
	at 10 miles	.35 to .50	.25 to .35
	at 20 miles	.20 to .35	.10 to .30
	at 30 miles	.10 to .25	.05 to .20
	at 40 miles	.05 to .20	.05 to .15
	at 50 miles	.05 to .15	less than .1

EXPLANATION

Earthquake acceleration is expressed as a fraction of gravity (g). Thus an acceleration of .5g corresponds to an acceleration which is 50% of the value of gravity. At a distance of 10 miles from the San Andreas fault, earthquake accelerations in bedrock are expected to be between .35g and .5g. Local ground conditions and other factors could either increase or decrease expected accelerations.

NOTE: The estimated maximum parameters are intended as estimates of the maximum earthquake characteristics that appear capable of occurring given presently known seismological and geological conditions. It should be recognized that (1) the approximations which are presented are for comparative purposes only, (2) there are differences of opinion among professionals on the reliability of such estimates, and (3) the approximations which are presented are not intended as design criteria for structures.

Sources:

¹ Estimates based on historic seismicity of the fault (Townley and Allen, 1939), behavior of faults of similar length (Tocher, 1958; Lida, 1965; Albee and Smith, 1967; Bonilla, 1967; Bonilla and Buchanan, 1970), and, where available, geologic history of displacement.

² Estimates based on historic offset associated with earthquakes in a specified magnitude range (Bonilla, 1970a, 1970b; Wallace, 1970; Algermissen, et al, 1972).

³ Estimates based on records of the duration of shaking of historic earthquakes (Greensfelder, 1973; Page, et al, 1972, p. 3).

⁴ Estimates based on the geologic history of the fault and on the general relationship that exists between earthquake magnitude and the length of the associated tectonic rupture. (Bonilla, 1970a, 1970b; Wallace, 1970).

⁵ Estimates based on records at the intensity of shaking associated with historic earthquakes. The empirical relationship between magnitude and maximum intensity is given by $M = 1 + (2/3)I$.

⁶ Estimates based on accelerogram records of selected historic earthquake. (Greensfelder, 1973, Schnabel and Seed, 1972).

Compiled by the Contra Costa County Planning Department.

GROUND SHAKING AND GROUND FAILURE

Most damage from a major earthquake is caused by ground shaking or related forms of ground failure. The 1971 San Fernando earthquake was typical in that roughly ninety-five percent of the dollar damage was attributable to these phenomena, and only five percent to surface faulting. It is predictable that the primary cause of damage in Contra Costa County from either a Great earthquake on the San Andreas fault (or other fault outside the County) or even a moderate earthquake originating on a fault within the County would be ground shaking and seismically-triggered ground failure.

Ground Shaking

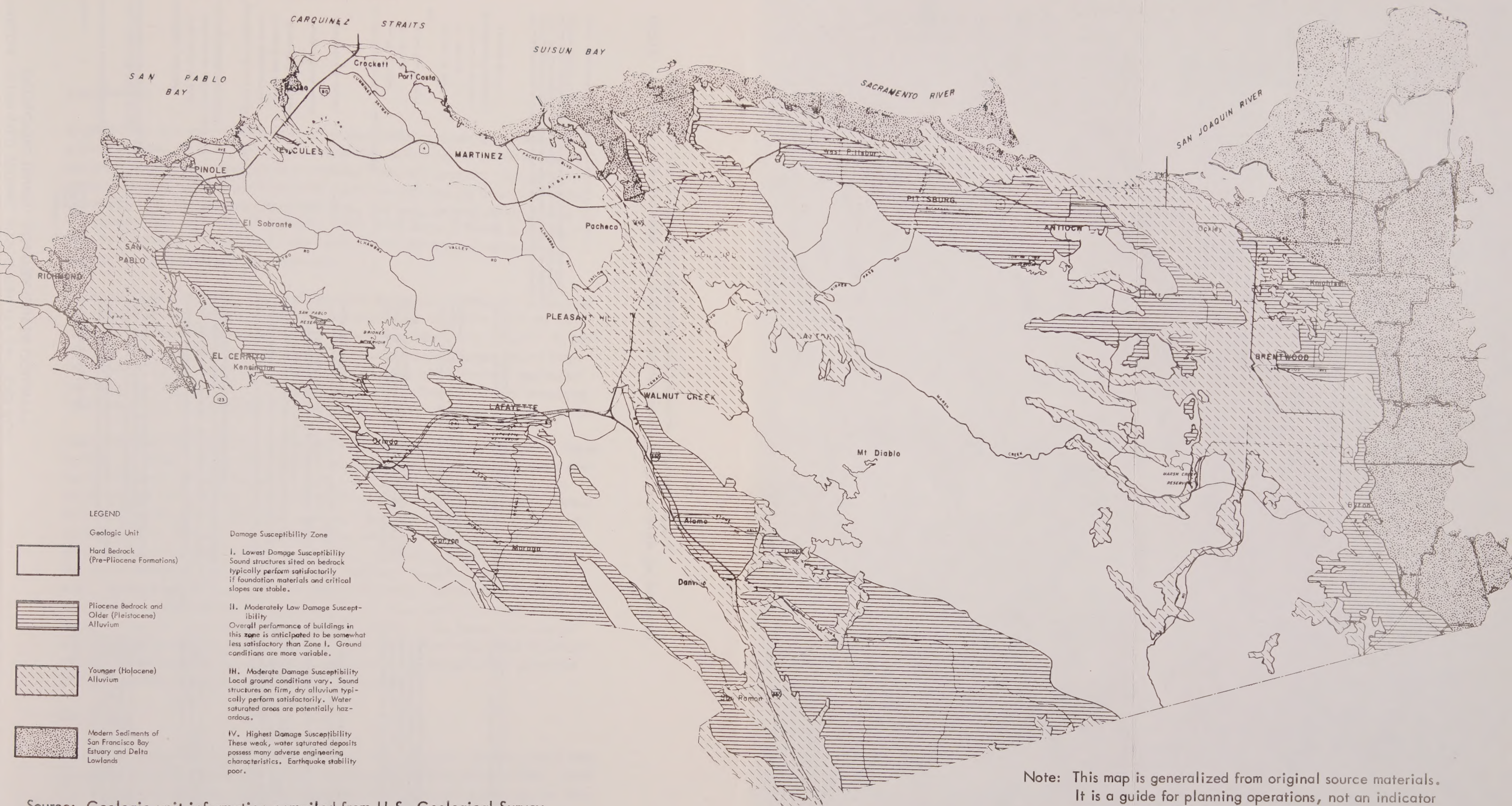
It was said earlier that local seismic ground shaking depends on not only the characteristics of the earthquake but on local ground conditions. Solid ground or rock tends to dampen ground motion while poorly consolidated and water-saturated materials amplify ground motion. During North America's two Great earthquakes of the Twentieth Century (San Francisco, 1906; Anchorage, 1964) it was observed that structures on solid ground near the epicenters frequently fared better than those located on weak materials located some distance away.

The ways different areas of the County would react to ground shaking have been mapped using approximation methods described in the Technical Background Report. As expected, the damage susceptibility of a particular building site is closely related to local ground conditions. Areas situated on hard bedrock (e.g., Briones Hills, Las Trampas Ridge, Diablo Range) may be expected to perform satisfactorily under earthquake conditions, provided that ground materials near the surface do not fail. Areas underlain by weakly consolidated sedimentary rocks (e.g., Pinole Ridge, Orinda, Alamo, Tassajara) are considered to possess a moderately low to moderate damage susceptibility.

The characteristics of ground motion in alluvial areas will differ somewhat from nearby bedrock areas (e.g., higher amplitudes, longer period, somewhat higher accelerations, etc.), and these differences may be important in the design of sophisticated structures. Areas underlain by firm, dry alluvium (e.g., floor of San Ramon Valley, Diablo Valley) are considered to possess a moderate damage susceptibility.

Areas underlain by young bay muds and deposits of the Sacramento-San Joaquin delta are considered to possess the highest damage susceptibility. Most of the County's development and population is located in areas of moderate to moderately low damage susceptibility.

MAP 3 SEISMIC SUSCEPTIBILITY



Note: This map is generalized from original source materials. It is a guide for planning operations, not an indicator of ground conditions on individual sites.

Source: Geologic unit information compiled from U.S. Geological Survey and California Division of Mines and Geology Mapping. Earthquake response interpretation by the Contra Costa County Planning Department

**TABLE 6 ESTIMATED SEISMIC SUSCEPTIBILITY FACTORS FOR
GEOLOGIC UNITS, CONTRA COSTA COUNTY***

Lithology	Susceptibility Factor (Modified Mercalli Units)	Zone	Geologic-Engineering Character	Remarks
FRANCISCAN FM AND IGNEOUS ROCK	0	I	Predominantly hard, clastic sedimentary rocks; massive to thin bedded; sequence includes some metamorphic rocks, altered basalts, and serpentine.	Historic records, as well as seismic ground response studies, suggest that these materials are safest in seismic behavior with respect to ground shaking. Limitations: slope stability conditions excellent to poor depending on lithology, thickness of weathered or sheared material, topographic and hydrologic setting, and other factors. Earthquakes can trigger landslides on unstable or marginally stable slopes.
GREAT VALLEY SEQUENCE ROCKS, EOCENE-MIOCENE SEDIMENTARY ROCKS	1/2		Stratified elastic sedimentary rocks, including mudstone, siltstone and sandstone; thin-to-thick-bedded; some massive, hard beds; weathered, jointed rock locally extends to depth of 20 feet and weathered rock ranges from soft to hard.	
PLEISTOCENE ALLUVIUM		II		
Older alluvial fan deposits	1		Includes stream terrace deposits in some narrow canyon; weathered; weakly consolidated.	Safe under dry conditions, but when wet the rocks become subject to failure; also, the greater the difference in physical properties of contiguous layers the greater the hazard. Hazard may increase on slopes if local reflected waves arise.
Deformed older sedimentary deposits			Poorly sorted silt, sand and gravel, less permeable than younger alluvial fan deposits.	
PLIOCENE SEDIMENTARY ROCKS	1		Heterogenous non-marine clastics; largely preconsolidated clayey sandstones and silty claystone; some hard lime-cemented sandstone.	
HOLOCENE AND LATE PLEISTOCENE ALLUVIUM		III		
Stream channel material	1 1/2		Loose, well-sorted sand and gravel; material presently being transported.	Subject to compaction and unequal settling, compaction greatest in dry (and coarser-grained) material. Saturated fine-grained sands and sandy soils may fail by liquefaction. When liquefaction occurs, increase in seismic intensity ranges up to 3 intensity units. Amplification of seismic waves greatest over thick alluvium; fan deposits hazardous on steep slopes.
Younger fluvial deposits	1 1/2		Unconsolidated elastics; predominantly fine-grained sand, silt, and silty clay.	
Younger alluvial fan deposits	1 1/2		Unconsolidated, mod. sorted, permeable fine-grained sand and silt; increasing abundant toward fan head and in canyons.	
Younger sand dune deposits	1 1/2		Normally loaded permeable sands; fine-grained; moderately compacted; thickness ranges from thin skin to over 100 feet.	Liquefaction hazard when saturated; dry sand subject to compaction.
Interfluvial basin deposits	1 1/2		Plastic, poorly sorted adobe clays; organic-rich, silty; slow in infiltration; consolidated increase with depth.	Not strongly hazardous if water table is at a depth of 25 feet or more. Hazard increases with increasing slope angle.
YOUNG BAY MUD (incl. non-engineered fill)		IV		
Less than 15' thick	2		Silty, clayey, sandy mud; small sand lenses; massive structureless; soft and fluid at top, increasingly consolidated at depth; high water content; low shear strength; high compressibility; low bearing strength, moderately high sensitivity.	Seismic ground response studies indicate that weakly consolidated, water-saturated sediments amplify ground motion. Additionally, at the high stress levels which accompany damaging earthquakes, such areas typically experience ground failure, including differential subsidence, ground cracking, lurching, lateral spreading toward a free face, liquefaction, and compaction.
15 - 30' thick	2 1/2			
Greater than 30' thick	3 1/2			
PEAT				
Less than 15' thick	2		Peat and associated organic silts and clay; underlain by normally loaded, water saturated fine grained clastics; peat approximately 50% combustible by weight; high water content; engineering properties comparable to young bay mud.	
15 - 30' thick	2 1/2			
Greater than 30' thick	3 1/2			
QUATERNARY SEDIMENTS				
Landslide deposits	1 1/2-3 1/2		Shallow and deep slides. Includes debris slides, slump blocks, earth flows and rockfalls. Composition of slide deposits highly variable.	Stabilized, dry slides relatively safe; active and/or wet slides extremely hazardous hazard greater on steep slopes, especially if local reflected waves arise.

*The susceptibility factor is the estimated increase in Modified Mercalli Intensity, and all susceptibility factors are relative to the Franciscan Formation and igneous rocks. The zone designations are an attempt to group rocks and surficial deposits into four major categories, based on their susceptibility to damage (see Gibbs and Eaton, U.S.G.S. open file map).

Source: Compiled by the Contra Costa County Planning Department.

NOTE: This table is generalized from original source materials. It is a guide for planning operations, not an indicator of ground conditions on individual sites.

Liquefaction

Liquefaction is a specialized form of ground failure caused by earthquake ground motion. It is a "quicksand" condition occurring in water-saturated, unconsolidated, clay-free sands caused by hydraulic pressure (from ground motion) forcing apart ground material particles and forcing them into liquid suspension. In the process, normally firm, but wet, ground materials are transformed into semi-liquid mixtures. The difference in states is comparable to the conversion of hard, wet beach sand into a loose material possessing the consistency of wet concrete.

Layers of ground material that are liquefied during an earthquake undermine the support of both natural landforms and man-made structures. Bluffs and ridges of unconsolidated material may slump under their own weight. Buildings and structures may sink and lean. Often used photographs taken after the 1964 Niigata, Japan earthquake show a group of multi-story apartment buildings leaning acutely or lying on their sides. These buildings remained intact, but this is not always the case when foundation support is diminished.

Areas underlain by hard bedrock at shallow depth are seldom subject to liquefaction, so these can be eliminated from consideration when large areas are being evaluated on a generalized basis. In Contra Costa County, this is about half of its land area, but almost all of that is hilly topography. Areas with deep water tables and those underlain by well consolidated ground materials typically have low or moderate liquefaction potentials. The cities of western central and northern Contra Costa County, as well as much of the agricultural land of eastern County, fall into these categories. However, geologically young and water saturated sandy sediments are highly susceptible to liquefaction, and extensive shoreline areas in western and northern County, and the delta in eastern County, have these characteristics. Soil engineering studies for subdivision and other major land development projects should make a careful appraisal of the liquefaction potential and the possible consequences of such liquefaction.

Landslides

Landslides and ground slippages are another form of ground failure which may be precipitated by significant ground motion produced by earthquakes. Areas that are subject to slides and slippages from other natural causes may be very hazardous under earthquake conditions. This is also to say that earthquake effects will be more extensive if the earthquake happens during the rainy season when ground conditions are more amenable to landsliding and ground slippage.

Within Contra Costa County, the Briones Hills and Diablo Range are areas marked by a succession of large and small geologically recent slides, many of them highly unstable. On a Countywide basis the two most important factors influencing the performance of slopes are the nature of the bedrock or surficial deposits and the slope angle. However, there are a number of factors which have a profound effect on the stability of a particular hillside. For example, the presence or absence of deep rooted vegetation; surface and subsurface drainage conditions; thickness and engineering characteristics of soils and underlying weathered, partially decomposed rock; orientation of bedding; or locally high rainfall can exert a controlling effect on the intensity of natural processes occurring on a particular hillside.

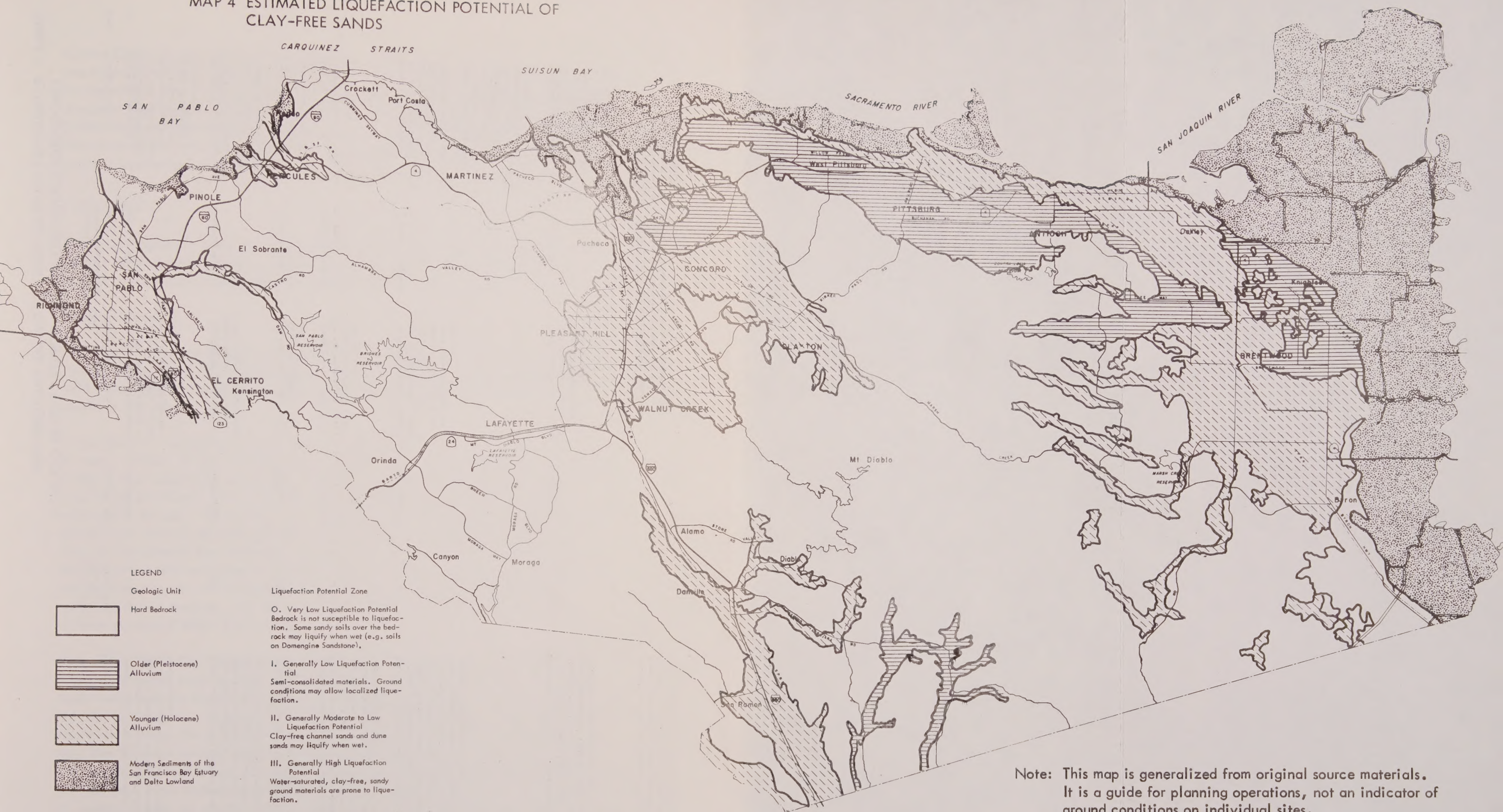
Planning Implications

In areas of substantial risk, the County General Plan and its component area plans should recognize local ground conditions as a primary determinant of land use. Generally, urban or suburban uses or intensities should not be planned for areas where geologic conditions would result in unacceptable risks to life and safety, and areas where the public costs of overcoming geologic deficiencies would exceed public benefits.

To the extent practicable critical facilities, structures involving high occupancies and public facilities should not be sited in areas of highest damage susceptibility. Where it is deemed essential to do so for the public welfare, these structures should be sited, designed and constructed with due consideration for the potential for earthquake damage due to ground shaking, associated ground deformation, seismically-triggered flooding, liquefaction potential, and landslide susceptibility.

In exercise of its responsibility to provide for the public safety in areas which are considered potentially hazardous in the event of an earthquake, approvals for public and private development projects should be contingent on geologic and engineering studies. Depending on circumstances, the requirement for geologic and/or soil investigations could be phased or staged, with an initial requirement for a reconnaissance report to be followed by a geologic hazards report or a preliminary soils report, where appropriate. The purpose of the reconnaissance report is to identify areas requiring special management and to recommend an exploration program to define and delineate any geologic hazard or potentially hazardous soil condition. The purpose of the second stage studies where needed, are to accurately identify developable areas and to recommend means of mitigating potentially hazardous conditions.

MAP 4 ESTIMATED LIQUEFACTION POTENTIAL OF CLAY-FREE SANDS



Note: This map is generalized from original source materials. It is a guide for planning operations, not an indicator of ground conditions on individual sites.

Source: Surficial deposit information compiled from U.S. Geological Survey and California Division of Mines and Geology Mapping. Liquefaction interpretation by the Contra Costa County Planning Department

Prepared by Contra Costa County Planning Department, December 1975.

Contra Costa County, California

TABLE 7 ESTIMATED LIQUEFACTION POTENTIAL FACTORS FOR
UNCONSOLIDATED SEDIMENTS, CONTRA COSTA COUNTY

Zone	Geologic Unit	Liquefaction Potential of Clay-Free Granular Layers	Occurrence and/or Distribution of Sands	Geologic Age	Depth of Water Table Below Surface (feet)	Remarks
iii	<u>Young Bay Sediments</u> Unconsolidated silt and clay with admixed abun- dant organic material; local peat, sand and gravel lenses or discon- tinuous beds.	Generally High	Clay-free sands are generally restricted to present and for- mer stream channels. Locally beach or dune sands may be present.	Late Holocene*	0-5	There is a general tendency for older, more deeply buried sands to be more compact than near surface deposits. Data show that approximately 75 percent of sands in younger bay sediments have a high lique- faction potential.
	<u>San Joaquin Delta Deposits</u> Mainly unconsolidated peat, organic clay, silt and fine-grained sand; irregularly interstratified.	Generally High	Predominantly flood plain and marsh deposits. Includes channel sands and dune sands.	Late Holocene	0-5	Loose, water saturated sands are present in most boring logs, and approximately 75 percent of the sands within 20 feet of the surface have a high liquefaction poten- tial. Below a depth of 20 feet sands have a much lesser but significant potential for liquefaction.
	<u>Stream Channel Material</u> Mainly loose, well- sorted sand and gravel.	Generally High	This material is restricted to present and former stream channels.	Historic	5-25	Largely restricted to material which is presently being transported during periods of normal runoff.
ii	<u>Dune Sands</u> Unconsolidated sand and silt.	Generally Moderate to Low	Transported and deposited by the wind; exposed on flank of Delta and underlie Delta peat deposits.	Early Holocene	10	Available data suggests that dune sands are less suscep- tible to liquefaction than the sand bodies associated with the Delta peat deposits, both because of their greater age and greater density. Additionally, because of their topographic expression, near surface sands have only seasonal or intermittent liquefaction potential.
	<u>Younger Alluvial-Fan, Fluvial and Interfluvial Basin Deposits</u> Fan deposits consist of moderately sorted sand and silt, with gravel becoming more abundant toward head of fan. Fluvial deposits consist of sand, silt and silty clay that locally con- tain variable amounts of organic matter.	Generally Moderate to Low	Fan deposits grade headward into terrace deposits. Levee and floodplain (fluvial) deposits accumulate at the outer edge of alluvial-fan deposits.	Holocene	5-25	Because of its greater age and greater density, Holocene channel sands are considered to be less susceptible to liquefaction than modern channel deposits. Granular, clay-free material may be considered to have seasonal or intermittent susceptibility to liquefaction; material below this depth has continual potential for liquefaction provided it is sufficiently loose.
i	<u>Older Alluvial Deposits</u> Poorly consolidated to semiconsolidated alluvial deposits of gravel, sand, silt and clay with subor- dinate fine-grained lacustrine deposits.	Generally Low	For occurrence, see discus- sion of younger alluvial-fan, fluvial, and interfluvial basin deposits.	Pleistocene	5-25	Liquefaction potential in Pleistocene alluvial deposits is low. Available penetrometer values indicate that approximately 10 percent of the clay-free deposits have a high liquefaction potential; approximately 60 percent have a low liquefaction potential.

*As used in this report, Late Holocene is considered to represent the period
of time that has elapsed since sea level attained its present position
(approximately 5,000 years before present) and initiated the modern cycle
of sedimentation.

NOTE: Information on the occurrence and character of surficial
deposits is generalized from original source materials.
This table is a guide for planning operations, not an in-
dicator of ground conditions on individual sites.

Contra Costa County, through its Planning Department should compile an administrative map series delineating areas which may be hazardous during earthquakes. The proposed maps should be presented in the form of a Ground Response Map (Seismic Susceptibility Map), Liquefaction Potential Map, and Landslide Susceptibility Map. Preferably this mapping should be done on a Countywide basis and at a scale of 1 inch = 2000 feet. The U.S.G.S. topographic quadrangel maps would map an ideal base of this information.

FLOODING

Flooding frequently accompanies an earthquake. It can be caused by fault rupture or by ground shaking, and through the collapse of dams and levees, the over-topping of empoundments, and tsunami ("tidal waves").

Levee Failure

Levees are a form of dam, but a kind that keeps water out of a lower area instead of confined in a higher empoundment. Because both levees and dams hold water at elevations higher than adjoining ground, the failure of either results in flooding.

Levee failure is common in some areas where levees rest on soft mud, silt, or peat. Often, levees in these areas are built of the same weak materials dredged from adjoining waterways. In the Delta area of California, a region of diked islands, flooding has occurred every several years from non-earthquake causes. Its islands were drained in the Nineteenth Century to create high quality agricultural land. Since then, the peat laden soil of many of the islands has oxidized, resulting in subsidence of their floors and the reconstruction of higher and heavier levees. Concurrently, the region has become popular for recreation. Boat movement on the waterways accelerates levee erosion, and increasing non-farm development worsens the disaster potential when levees fail.

Part of the Delta lies in and adjacent to eastern Contra Costa County (technically, it is the area less than ten feet above sea level), and this area has been vulnerable to flooding. Delta islands here have flooded five times in the last forty years. In general the flooded islands have been reclaimed. However, Franks Tract State Park (a lake) and Big Break are visible reminders that it is not always practical or economical to reclaim drowned islands. The threat of levee failure during periods of high water is constant. During the last such high water period in January 1973 (which was not the highest on record) levees on several islands were over-topped, or within a few inches of being over-topped, and "weeping" behind the levees was discovered in at least one place.

There are two types of levees in the Delta lowlands of Contra Costa County. Approximately eighty to ninety percent of the levees are non-project (private) levees. These levees are non-engineered structures which are not forced to meet any standards of maintenance. According to the Corps of Engineers and the California Department of Water Resources, many reaches of non-project levees are in poor condition and in need of rehabilitation. The remaining ten to twenty percent of the Delta levees of Contra Costa County are direct agreement levees. These are private levees which have been rehabilitated or modified by the Corps of Engineers and are, therefore, required to be maintained to specific standards in accordance with Federal and State regulations.

With regard to seismic safety, it is pertinent to note that even the levees which have been constructed by the Corps of Engineers are only intended to provide protection against erosion and flooding. They are not intended to provide protection against the effects of a severe (potentially damaging) earthquake. Thus, the seismic survivability of the Delta levee system is high questionable.

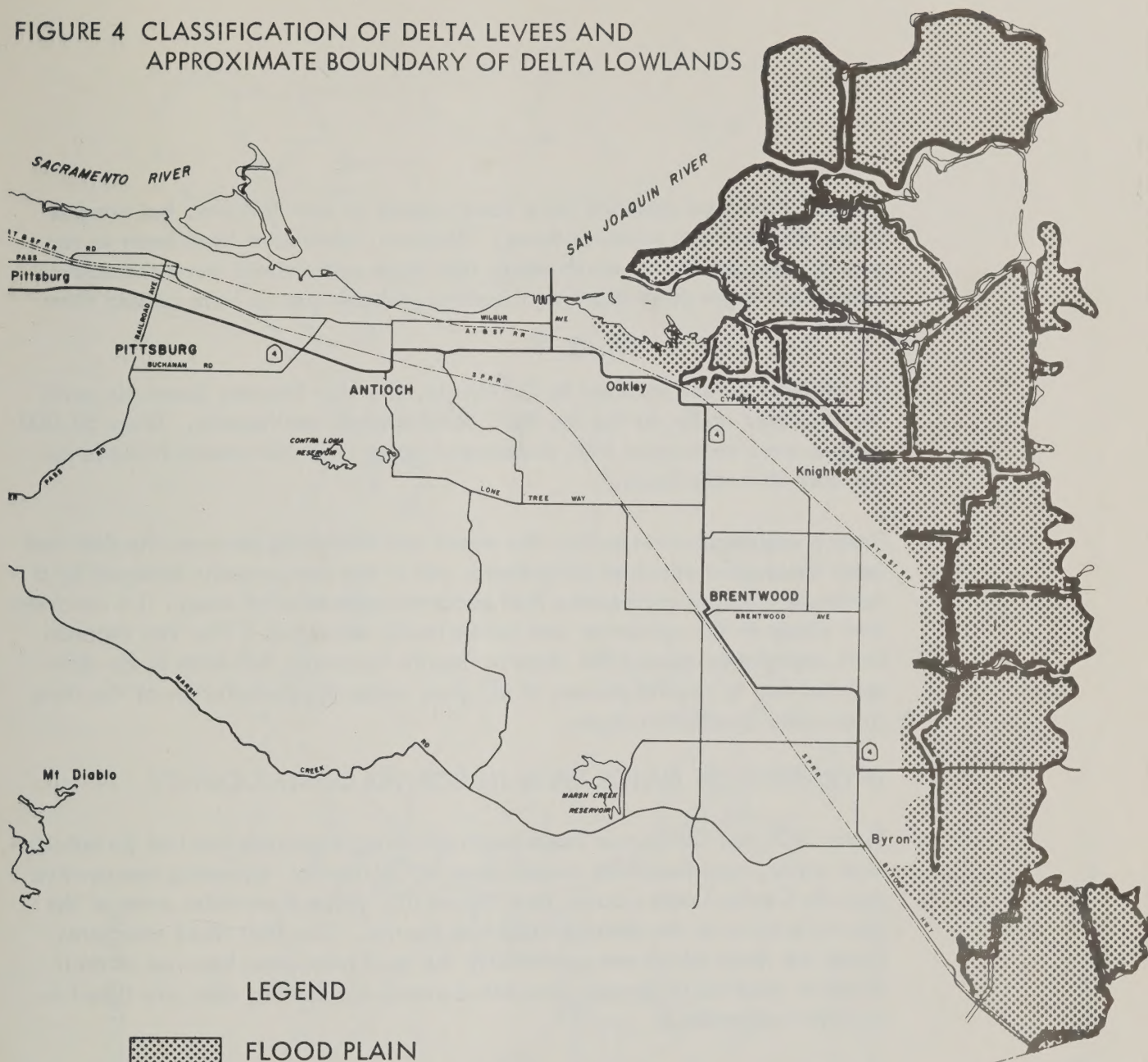
It is apparent that earthquake effects in the Delta would be compounded by the nature of its fine-grained, water-saturated, unconsolidated ground materials. These effects have been discussed previously in this Element.

Although the Delta historically has been one of the more seismically active areas of California and has experienced powerful earthquakes in the past, its levee system has been subjected to only mild stresses since the late Nineteenth Century. (The forces of the 1906 San Francisco earthquake, the possible exception, appear to have been transmitted southward toward the lower San Francisco Bay area rather than eastward toward the Delta.)

Dam Failure

However remote, the potential for dam failure is a matter of great concern. This is especially true in settled areas, because the uncontrolled release of an impoundment can send a surge of water downstream at great force and speed, and inundate large areas. Large dams which are regulated by the State of California, are designed to withstand overload stresses (large ones are difficult to destroy even in wartime) but earthquakes are capable of exerting some of the most powerful forces in nature. Interestingly, a trickle of water from a small breach in a dam can erode the facility and grow to a rush of water to cause its failure. Fault movement or ground shaking could supply the breach.

FIGURE 4 CLASSIFICATION OF DELTA LEVEES AND
APPROXIMATE BOUNDARY OF DELTA LOWLANDS



LEGEND



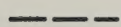
FLOOD PLAIN

Area less than 10 feet above sea level.



DIRECT AGREEMENT LEVEES

Private levees which have been rehabilitated or modified by Corp of Engineers; maintained to specific standards in accordance with Federal and State regulations.



NON-PROJECT LEVEES

Private levees which are non-uniform in cross section and are not forced to meet any standards of maintainance; many reaches of levee are in need of rehabilitation.

Several American disasters have been caused by dam failures, but none of these resulted from seismic causes. However, dams here have been so severely damaged during earthquakes that large populations were endangered. Somewhat larger or stronger earthquakes probably would have caused them to fail.

In the most recent incident in California, the Van Norman Reservoir earth dam slumped badly during the 1971 San Fernando earthquake. Over 50,000 people were evacuated from downstream areas until the reservoir could be lowered to a safe level.*

From a regulatory standpoint, the event was disturbing because the dam had been thoroughly checked beforehand, yet it was dangerously damaged by a moderate strength earthquake that occurred several miles away. (A concrete dam closer to the epicenter was not seriously damaged.) The Van Norman Dam experience caused the state to require hydraulic fill dams to be re-inspected and to require owners of all dams under the jurisdiction of the state to develop inundation maps.

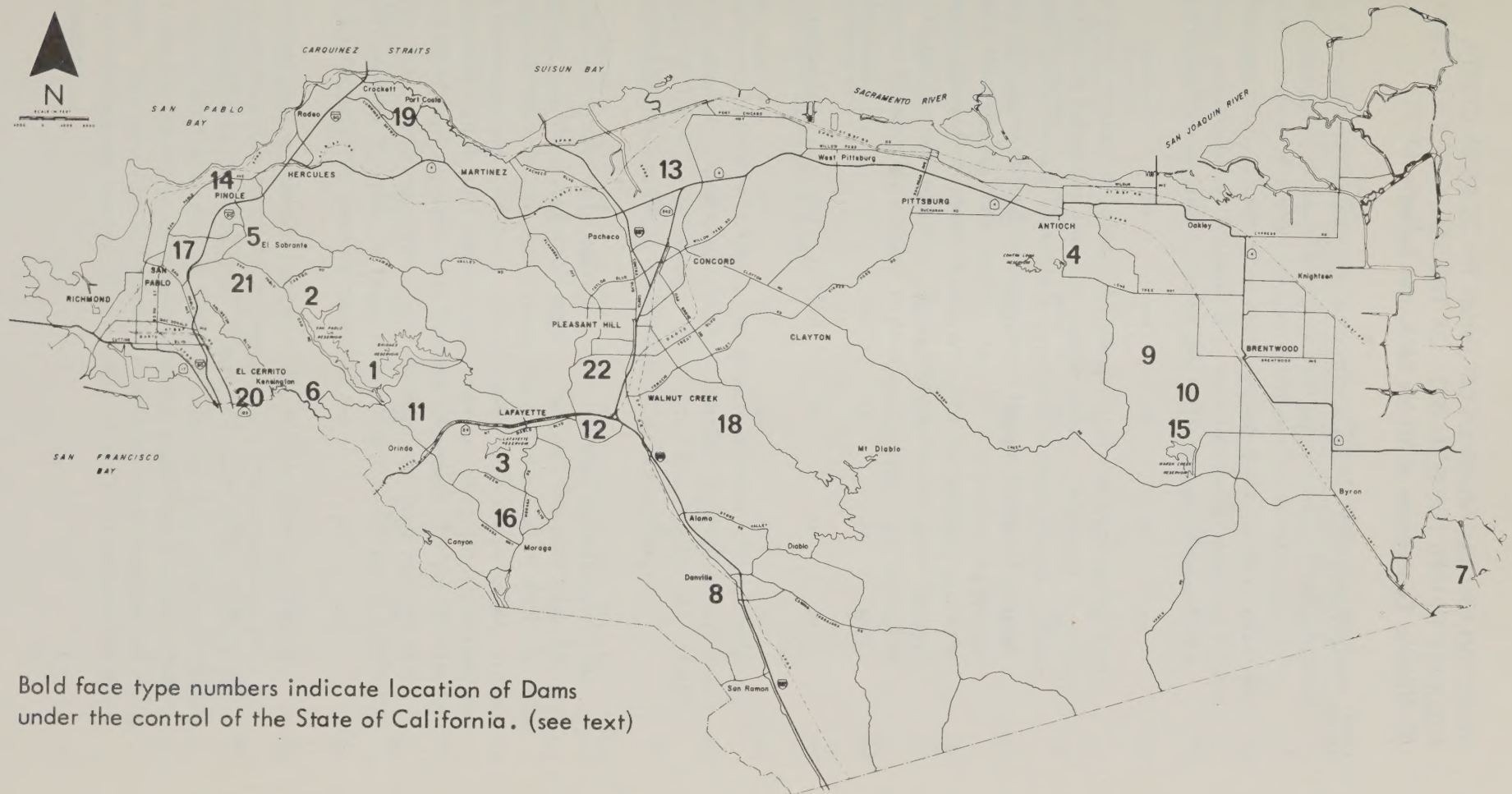
INVENTORY OF MAJOR DAMS IN CONTRA COSTA COUNTY

Since 1929 the California Department of Water Resources has had jurisdiction over major, non-federally owned dams in California, including twenty-two dams in Contra Costa County (see Figure 5). Table 8 contains some of the characteristics of the dams under State control. The first three structures listed are those which are potentially the most hazardous because of their location relative to densely populated areas; succeeding dams are listed in alphabetical order.

By statute, dams falling under State control are those which are either, (1) twenty-five feet or more high and impound more than fifteen acre feet of water, or (2) are more than six feet high and impound fifty or more acre feet of water. The Division of Safety of Dams within the Department of Water Resources has broad responsibilities over such dams and reservoirs

*As this Element was being prepared for publication, a series of earthquakes in the Oroville, California area, in the minor to moderate range appear to have caused no damage to the earthen Oroville Reservoir Dam, the largest of its kind in California. Preliminary reports indicate that the earthquake was generated by a fault which had not moved in two million years.

FIGURE 5 STATE CONTROLLED DAMS



Bold face type numbers indicate location of Dams under the control of the State of California. (see text)

TABLE 8 **SELECTED CHARACTERISTICS OF DAMS IN CONTRA COSTA COUNTY UNDER THE CONTROL OF THE STATE OF CALIFORNIA**
(California Department of Water Resources Bulletin 17-71)

Dam	Number (see fig.)	Storage Acre (ft.)	Height (ft.)	Crest Length (ft.)	Type	Year Completed	Stream	Remarks
Briones	(1)	67,500	273	2,100	Earth	1964	Bear Creek	EBMUD (owner) 21, 1N, 3W Upstream from San Pablo Dam
San Pablo	(2)	43,193	170	1,250	Hydraulic Fill	1920	San Pablo Creek	EBMUD (owner) 12, 1N, 4W 3 mi. from Hayward Fault
Lafayette	(3)	3,500	132	1,200	Earth	1929	Lafayette Creek	EBMUD (owner) 36, 1N, 3W Crest elevation 467 feet
Antioch	(4)	722	30	450	Earth	1935	San Joaquin (tributary)	City of Antioch (owner) 36, 2N, 1E
Argyle #2	(5)	22	27	875	Rect.	1970	San Pablo Bay	EBMUD (owner) 27, 2N, 4W
C. L. Tilden Park	(6)	243	88	355	Earth	1938	Wildcat Creek	E. B. Regional Park District (owner) 25, 1N, 4W
Clifton Court Forebay	(7)	29,000	34	39,000	Earth	1970	Old River (tributary)	State Dept. Water Resources 20, 1S, 4E
Danville	(8)	45	75	765	Earth	1961	San Ramon Creek	EBMUD 25, 1S, 1W
Deer Creek	(9)	233	28	900	Earth	1963	Deer Creek	Contra Costa County, FCWCD 21, 1N, 1E
Dry Creek	(10)	362	30	470	Earth	1963	Dry Creek (West of Brentwood)	Contra Costa County, FCWCD (owner) Crest elev. 139 feet
Lake Orinda	(11)	220	45	360	Earth	1935	Cascade Creek	Orinda Country Club (owner) Crest elev. 535 ft. 34, 1N, 3W
Leland	(12)	60	41	945	Earth	1955	Las Trampas Creek	EBMUD (owner) 33, 1N, 2W Crest elevation 361 feet
Mallard	(13)	3,113	30	11,000	Earth	1930	Suisun Bay (tributary)	CCCWD (owner) 13, 2N, 2W
Maloney	(14)	68	107	620	Earth	1960	Pine Creek (tributary)	EBMUD (owner) 21, 2N, 4W
Marsh Creek	(15)	4,425	59	1,540	Earth	1963	Marsh Creek	Contra Costa County, FCWCD Crest elev. 204 ft. 35, 1N, 2E
Moraga	(16)	36	37	210	Earth	1965	Las Trampas Creek (tributary)	EBMUD (owner) 18, 2N, 4W
North	(17)	244	82	1,080	Earth	1961	Rheems Creek (tributary)	EBMUD (owner) 32, 2N, 4W Crest elevation 220 feet
Pine Creek	(18)	225	87	320	Earth	1956	Pine Creek	Contra Costa County, FCWCD (owner) 32, 1N, 1W
Port Costa	(19)	39	45	240	Earth	1890	Carquinez Strait (tributary)	William L. Rich (owner) Crest elev. 105 ft. 3, 2N, 3W
San Pablo Clearwater	(20)	17	42	627	Earth	1922	Cerrito Creek	EBMUD (owner) 27, 1N, 4W Crest elevation 242 feet
Sabrante Clearwater	(21)	25	28	1,032	Earth	1964	San Pablo Creek (tributary)	EBMUD (owner) 3, 1N, 4W
Walnut Creek Clearwater	(22)	25	102	890	Earth	1967	Grayson Creek (tributary)	EBMUD (owner) 21, 1N, 2W

to ensure that they provide adequate standards of public safety consistent with the earthquake motions to which they may be subject. These responsibilities include review of plans and specifications for construction of a new dam or for repairing, altering, or removing an existing dam. Furthermore, they have responsibility for periodic reevaluation of existing structures, and the owner is required to make any improvements found to be necessary.

According to the Division of Safety of Dams, all of the dams under their authority provide an adequate level of public safety. None of the major dams in Contra Costa County straddle known active fault traces. However, all dams can be expected to experience severe levels of ground shaking at some time during their useful life. It is important to recognize that construction of all these dams, with one exception, postdate the 1906 San Francisco earthquake. Thus, they have not experienced a level of seismic loading equivalent to that accompanying a moderate to great earthquake.

SMALL, NON-REGULATED DAMS

A source of concern is that only the larger dams and reservoirs are publicly regulated. The regulation and supervision of smaller sized dams and reservoirs is left open to local jurisdictions. Within the Bay Region only Marin and Sonoma counties are known to have adopted such ordinances.

In Contra Costa County the only agency with a general knowledge of the age, construction and history of small dams is the Soil Conservation Service. This federal agency will design and inspect the construction of dams for those owners who will cooperate with them. To promote such cooperation, there are federal programs which will defray some construction costs, provided the dam is engineered to Soil Conservation Service standards. It should also be recognized that the Soil Conservation Service does not issue permits and a prospective dam builder is under no legal requirement to design or construct the dam to Soil Conservation Service standards.

The safety of these smaller dams is not primarily a seismic safety matter. Failure is more commonly a result of inadequate spillway capacity, or a lack of maintenance after construction. One small dam in the County has been overtopped at least once during the past fifteen years. Water flowing over the crest has succeeded in cutting a prominent gully in the downstream face of the dam. This structure is probably weakened and in danger of being breeched if it is overtopped again. The seismic safety of these smaller dams is largely unknown.

RECENT LEGISLATION

Senate Bill 1632 of 1974 specifies that owners of dams under the jurisdiction of the State of California are required to prepare inundation maps for use in disaster planning. The initial recommendation for this law came from the Advisory Group to the Legislature's Joint Committee on Seismic Safety. As initially proposed the inundation maps were also to be considered in land use decisions made by affected local jurisdictions.

The law requires that dam owners prepare an inundation map that assumes the reservoir is at maximum capacity and failure of the dam is essentially total and rapid. As they are completed the maps are to be submitted to the State Office of Emergency Services for technical review. Those maps which are found to be adequate are distributed to the affected local jurisdictions; maps which contain serious errors are being returned to the dam owner for revision. To date the County has received eighteen approved inundation maps. The remaining maps are to be distributed to the County as they are prepared. The County Office of Emergency Services estimates that the required inundation maps should be available to the County and affected cities no later than mid-1976.

It should be recognized that the risks to life and property are not uniform throughout the inundation area. For example, at the boundary of the inundation area water depths are approximately curb height and the rush of water would be reduced in this area. Thus, evaluations of risks to a specific site involves several factors, including (a) velocity and depth of water, (b) local topography, (c) duration of flooding, and (d) design of the structure and other factors.

TSUNAMI

Tsunamis are sea waves created by undersea fault movement. Traveling through the deep ocean, a tsunami is a broad and shallow, but fast moving, wave that poses little danger to most vessels. When it reaches the coastline, however, the wave form pushes upward from the ocean bottom to make a high swell of water that breaks and washes inland with great force. The waves may reach fifty feet in height on unprotected coasts, and one on record (Japan, 1896) killed nearly 30,000 people and destroyed over 10,000 homes. Several people were drowned in Crescent City, California, in 1964 by the tsunami generated by the "Good Friday" Alaska earthquake.

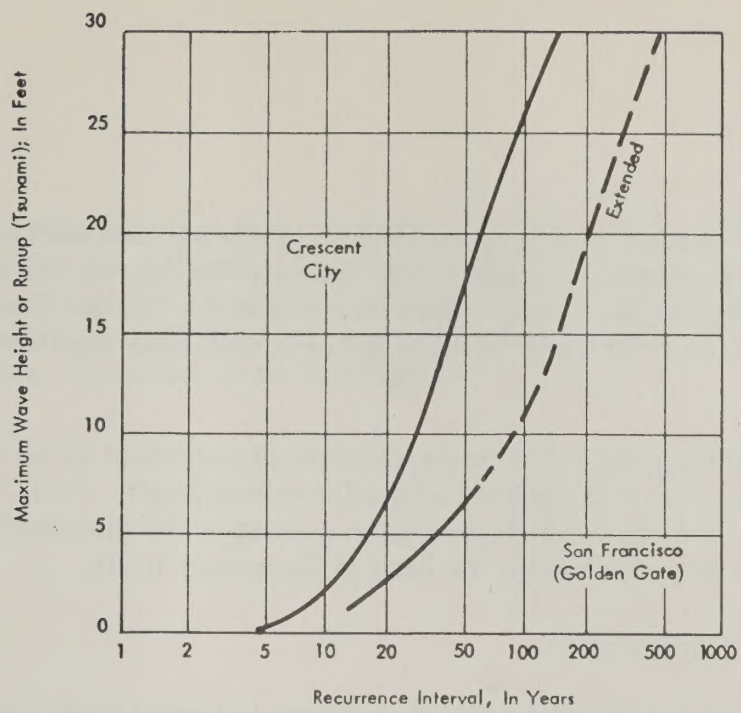


FIGURE 6a TSUNAMI RECURRENCE

Frequency of occurrence for maximum tsunami waves at the Presidio in San Francisco and at Crescent City.

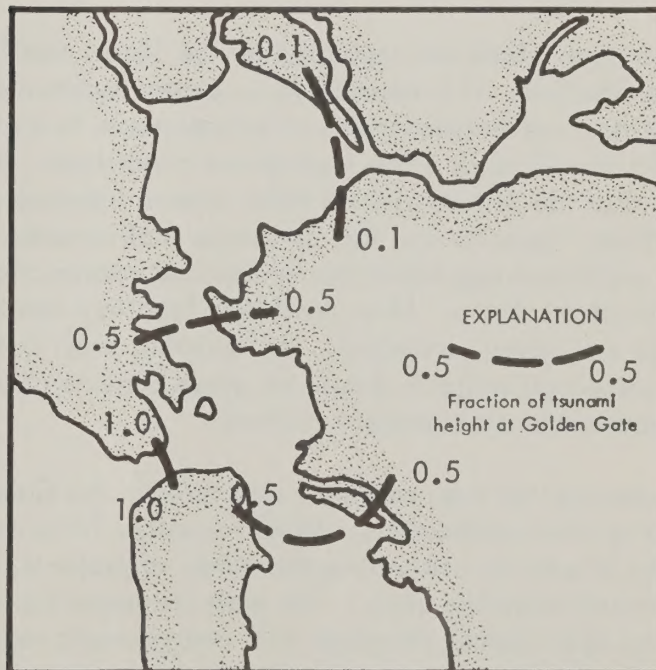


FIGURE 6b TSUNAMI ATTENUATION

Tsunami attenuation in San Francisco Bay based on the May 1960 and March 1964 tsunamis.

Source: U.S. Geological Survey, Basic Data Contribution 52, 1972.

Historic records of the Bay Area used by one study indicate that nineteen tsunamis have been recorded in San Francisco Bay during the period 1868-1968. The maximum wave height recorded at the Golden Gate Tide gage was 7.4 feet, which may be regarded as a reasonable maximum for future events.

The available data indicates a systematic diminishment of wave height from the Golden Gate to the head of the Carquinez Strait. Thus, the damage potential of a tsunami will tend to be greater in the Richmond area and show a general decrease toward the head of Carquinez Strait.

Planning Implications

Major dams are the most critical structures in Contra Costa County in terms of the potential loss of life that could result from their failure during an earthquake. After State safety studies and inundation studies have been completed, consideration should be given to revising the County's General Plan and its land development ordinances to provide for use of downstream land appropriate to the findings.

Unlike the dams which are regulated by the State, small earthen dams are not now controlled. It is reasonable to expect extensive slumping, cracking, fissuring, and fragmentation of embankments in a number of non-engineered installations under earthquake conditions. It should be noted, however, that the failure of such dams is more frequently a result of inadequate spillway capacity and lack of proper maintenance. The County should adopt an ordinance regulating the design and construction of dams not under the control of the State. New small dam locations would be better reviewed under land use permit procedures, and existing small dams up-stream from proposed development projects should be given consideration in environmental impact reports and other project reviews.

Delta levees are the most sensitive structures in the County in terms of potential flooding from earthquakes. Until recently, little attention was given to earthquake stresses in evaluating the safety of projects, but this is a subject which warrants exacting study. For projects proposing uses other than agriculture and open space, thorough soils and geologic reports should be required in the review process; these should assess the stability and dynamic response of the levees, the underlying soils, and the consequence of failure. Lacking such information, agricultural and other land uses not involving substantial human occupancy is appropriate for areas subject to inundation from levee failure.

In areas where mapping indicates that a tsunami hazard may exist, project reviews should address the adequacy of protection for structures for human occupancy, and particularly critical structures, and potentially dangerous commercial or industrial facilities (e.g., plants for the manufacture or storage of explosive, flammable or toxic materials).

HAZARDOUS STRUCTURES AND PHYSICAL FACILITIES

INTRODUCTION

The preceding discussion has dealt with seismicity and seismic geology in order to explain the causes and effects of earthquakes, and to explain what these mean to Contra Costa County. It has been shown that Contra Costa County is a seismically active area where human settlements and buildings are expected to endure major earthquakes during their useful lives. These earthquake impacts, it was noted, will vary with the quality of the soil and bedrock underneath the developments and buildings. Now, this part of the plan will focus on the public policy considerations for constructing individual buildings to withstand earthquakes, and in locating important public-serving facilities on this dynamic landscape.

SEISMIC RISK

Before taking up the subject of structural safety, it is necessary to discuss seismic risk because the measures taken to make structures safe during earthquakes depend on the extent of the danger that structures are exposed to as well as the public's willingness to take risks.

A public jurisdiction adopting policies for the location of land uses and public service facilities (such as in its General Plan), or enacting building standards (such as in its building code), is exercising its judgment on the degree of seismic risk that it will accept. (Too often, this life-and-death judgment is not publicly evaluated and explicitly set forth but is implicit in the various criteria and standards it uses in its decision-making process.)

As desirable as it would be to completely eliminate seismic risks to both people and property, society simply doesn't have the resources and, possibly not even all the required technology to accomplish this, or even to approximate it, in the foreseeable future. The near total elimination of earthquake risk would require that new structures be over-built as far as other purposes are concerned, and that virtually all existing structures would be reinforced, rebuilt, or removed.*

*As will be pointed out in a succeeding section, the basic information to identify which existing buildings will need particular modifications to achieve a specified level of seismic safety is generally lacking at the present time. So, it is not possible with current means to say how big of a project it would be to achieve absolute seismic safety, or what this aspect alone of risk analysis would cost.

If the total elimination of risk from seismic causes is not possible at the present time, then it would be desirable for the purposes of objective selection to have the capability to "price" the costs and benefits of alternative seismic safety plans and programs (or safety standards) in terms of their comparative abilities to save lives and protect persons and property. However, this kind of cost-benefit quantification also is not yet possible (for many reasons), so the determination of acceptable risk and the selection of acceptable seismic safety programs must be made qualitatively.

This Seismic Safety Element already has stated general priorities in its Goals statement, where it gives precedence to the protection of human lives over the protection of real estate and property, and states that the reduction of damage to property must be balanced against financial capability, the quality of life, and environmental quality. In other words, it advocated an approach to seismic safety in which risk to lives should not be considered to be acceptable, but buildings and other property may be expendable.

The policies and recommendations of this Seismic Safety Element, individually and in combination, are intended to further these goals; but, it is obvious that since several recommendations point to the need for specific studies, the goals are not going to be accomplished in the near future, or with present means. Rather, it is expected that the implementation of the Element and other public programs will result in a continuing reduction of risk to persons and then to property.

With particular reference to the structural aspects of seismic safety, the California Legislature's Joint Committee on Seismic Safety advocated an approach that Contra Costa County should follow (see Table 9). The Committee recommended that additional building (or project) costs were warranted to achieve desired levels of safety in primarily new structures. Four levels of acceptable risk were identified, each justifying a different level of expenditure.

For these kinds of structures which must function after an earthquake or whose failure could result in catastrophe, the Committee recommended simply that safety had to be achieved at any cost. Increases in project cost in the range of five to twenty-five percent were thought to be reasonable for other kinds of emergency facilities, and between five and fifteen percent for high occupancy structures. At the lower end of the scale, very minor increases in the range of one to two percent in most cases were considered to be adequate and reasonable for most residential and other structures.

TABLE 9 A SCALE OF ACCEPTABLE RISKS

Level of Acceptable Risk	Kinds of Structures	Extra Project Cost Probably Required to Reduce Risk to an Acceptable Level
1. Extremely low ¹	Structures whose continued functioning is critical, or whose failure might be catastrophic: nuclear reactors, large dams, power intertie systems, plants manufacturing or storing explosives or toxic materials	No set percentage (whatever is required for maximum attainable safety)
2. Slightly higher than under level 1 ¹	Structures whose use is critically needed after a disaster: important utility centers; hospitals; fire, police, and emergency communication facilities; fire stations; and critical transportation elements such as bridges and overpasses; also smaller dams	5 to 25 percent of project cost ²
3. Lowest possible risk to occupants of the structure ³	Structures of high occupancy, or whose use after a disaster would be particularly convenient: schools, churches, theaters, large hotels, and other high-rise buildings housing large numbers of people, other places normally attracting large concentrations of people, civic buildings such as fire stations, secondary utility structures, extremely large commercial enterprises, most roads, alternative or noncritical bridges and overpasses.	5 to 15 percent of project cost ⁴
4. An "ordinary" level of risk to occupants of the structure ^{3,5}	The vast majority of structures: most commercial and industrial buildings, small hotels and apartment buildings, and single family residences.	1 to 2 percent of project cost, in most cases (2 to 10 percent of project cost in a minority of cases) ⁴

¹ Failure of a single structure may affect substantial populations.

² These additional percentages are based on the assumption that the base cost is the total cost of the building or other facility when ready for occupancy. In addition, it is assumed that the structure would have been designed and built in accordance with current California practice. Moreover, the estimated additional cost presumes that structures in this acceptable-risk category are to embody sufficient safety to remain functional following an earthquake.

³ Failure of a single structure would affect primarily only the occupants.

⁴ These additional percentages are based on the assumption that the base cost is the total cost of the building or facility when ready for occupancy. In addition, it is assumed that the structures would have been designed and built in accordance with current California practice. Moreover the estimated additional cost presumes that structures in this acceptable-risk category are to be sufficiently safe to give reasonable assurance of preventing injury or loss of life during and earthquake, but otherwise not necessarily to remain functional.

⁵ "Ordinary risk": Resist minor earthquakes without damage; resist moderate earthquakes without structural damage, but with some non-structural damage; resist major earthquakes of the intensity or severity of the strongest experienced in California, without collapse, but with some structural as well as nonstructural damage. In most structures, it is expected that structural damage, even in a major earthquake, could be limited to repairable damage. (Structural Engineers Association of California).

The County should regard these cost ranges as reasonable guidelines in determining costs for its own projects and in setting standards for private construction.

STRUCTURAL DAMAGE IN EARTHQUAKES (SAN FERNANDO EXAMPLE)

In an earthquake, the major loss of life and destruction to property occurs as a result of damage to buildings. For example, during the moderate 1971 San Fernando earthquake, which centered in a suburban area of relatively modern buildings, damage to structures alone exceeded \$500 million and there were fifty-eight deaths. The damage to the buildings may be summarized as follows:

1. Family dwellings. Frame dwellings withstood earthquake forces quite well. In the area of strong ground shaking, 15,000 dwellings were damaged to varying degrees; of these 465 were declared unsafe and chimneys and other inflexible building elements tended to be damaged. Wide spans in garages and elsewhere were susceptible to failure. Fixtures, such as water heaters, were toppled or damaged even when the buildings housing them were little affected.
2. Apartments and commercial buildings. A total of sixty-two apartment houses and 372 commercial structures were so severely damaged that they had to be declared unsafe and evacuated.

Occupants of residential buildings had to be provided with emergency housing. Damage to commercial buildings slowed economic recovery.

3. Old, masonry buildings. Old reinforced brick buildings were heavily damaged, not only in the area of strong ground shaking, but as far away as downtown Los Angeles (fifteen to twenty-five miles from the source of the earthquake waves).
4. High-rise buildings. Modern high-rise buildings received only a partial test, since they were not located in the epicentral area. Those buildings in the Los Angeles area, ten to twenty-five miles from the center of the earthquake did not sustain structural damage. This earthquake did trigger a considerable amount of non-structural damage, including cracking of interior partitions, breakage of windows, falling of ceilings and light fixtures, overturning of office furniture; and failure of elevators, air conditioning equipment and emergency power supplies.

The San Fernando earthquake can serve as a model of earthquake effects on structures for Contra Costa County, which is also extensively developed in modern, suburban density, low-rise buildings, but has some older structures and is beginning to experience higher density development and higher buildings. It shows that most modern buildings, especially frame structures, will survive at least a moderate earthquake and protect their occupants. But, it also shows that greater attention must be given to both geologic conditions and construction standards in new building projects, and to the performance of older buildings which were designed before Riley Act (1933) standards influenced building codes.

STRUCTURAL SAFETY PROGRAM COMPONENTS

Seismic Design Provisions of the Uniform Building Code

The present seismic design provisions of the Uniform Building Code, which is followed by Contra Costa County, are based on professional association recommendations promulgated by California structural engineers in 1967. Recognizing the need to improve the code (as a result of knowledge gained from studies of recent earthquakes and other research), and acknowledging that the task of revision is greater than voluntary associations can reasonably provide, the Legislature's Joint Committee on Seismic Safety has recommended that the State of California finance an updating study that could serve as the basis of strengthening the minimum seismic design requirements of all building codes with the State. This has not occurred. However, the International Conference of Building Officials has formulated building code revisions which meet part of the need (see below).

Six areas of concern were identified by the Joint Committee on Seismic Safety:*

1. Regulation of design and anchorage of non-structural building items such as: exterior architectural material and veneers, pre-cast pre-fabricated panels, elevator equipment, light fixtures, mechanical equipment, ceiling systems, electric power equipment, non-bearing partitions, interior finish materials, glazing, and shelving, cabinets, racks, containers related to storage facilities.

*Meeting the Earthquake Challenge, 1974 (p. 91)

2. Augmentation of (seismic) lateral design forces and provision for vertical acceleration design forces.
3. Consideration of the influence of the type and depth of soils at the building site on the dynamic behavior of building structures.
4. Improvement of criteria for seismic connection details building joints, and pre-fabricated building system interface.
5. Codification of stricter requirements to insure the unimpaired function and structural integrity of emergency exits and stairways.
6. Enactment of separate code requirements to deal with higher standards for emergency service facilities.

In view of the known deficiencies in the Uniform Building Code, the International Conference of Building Officials has prepared the "1976 amendments" to the Uniform Building Code. This package of proposed code revisions addresses some, but not all, of the subjects of concern identified by the Legislature's Joint Committee on Seismic Safety. These code revisions should be adopted and enforced as soon as possible.

It should be recognized that improved codes are essential to achieving a higher degree of seismic safety. However, equally important, if not more important, are careful plan checking and enforcement of existing code standards. In this regard it is pertinent to note that the professional staff of the County Building Inspection Department includes experienced structural and grading engineering personnel (who are not typically present in smaller agencies).

Structural Hazards Study

The major technical impediment to the development of programs to correct hazardous structural conditions is the unavailability of comprehensive and systematic inventory information. Conventional sources of generalized structural information, such as the Federal Census of Housing and Land Use inventories for the general plan, are not adequate to make even large-area policy planning assessments of where problem structures are located, what their problems are, and how many structures are involved. Similarly, normal sources of information on individual structures are inadequate to provide (recently at least) the kinds of information needed for implementation and enforcement programs. In both cases, special inventories and

specialized reviews of existing data sources are necessary to prepare seismic safety programs dealing with structures.

Because the vast majority of local jurisdictions do not have a positive program to identify existing hazardous buildings and have not formulated plans and regulations for the abatement of hazards found unacceptably high, the Joint Committee on Seismic Safety recommended that action be taken at the State level. Their report (*Meeting the Earthquake Challenge*, 1974, p. 18) recommends the creation of a California Commission of Seismic Safety. As proposed, one of the functions of this commission would be to develop a program of hazardous building abatement, concentrating first on older structures and critical structures which are hazardous because of local geologic-seismic conditions on the site.

If the state does not prescribe a program to study hazardous structures within two years of the County's adoption of the Seismic Safety Element, the County Planning Department should draft a work program to conduct its own study. Such a program would pertain to the unincorporated areas of the County and to those cities wishing to participate. It could be modeled after the recommendations of the report prepared by the Advisory Group on Government Organization and Performance (*Meeting the Earthquake Challenge*, 1974, p. 166-167). Briefly, the first phase of their program calls for making an inventory of high-occupancy, critical* and older structures, and outlines a strategy for the elimination of buildings found to be hazardous either because they possess serious structural deficiencies or because of geologic-seismic conditions on the site. In the second phase of the program, less hazardous buildings are identified or estimates made of their prevalence, location, and degree of hazard posed. Using this data, a program could be developed to reduce seismic risk in realistic stages over a period of years.

*With regard to seismic safety, critical facilities may be defined as those facilities which are needed for disaster recovery, such as the disaster response communications center, hospitals, police and fire stations; important community facilities, such as schools and civic centers; utility facilities, including structures for the distribution of water, sewage, power and fuel; transportation facilities, including highways, rapid transit structures and airports; and major industrial and military facilities which are potentially hazardous because of the nature of their operations. Other structures which should be considered in a similar manner are those whose failure could result in a high loss of life such as high-rise buildings and theaters; and structures of involuntary occupancy such as jails.

RECONSTRUCTION AND REDEVELOPMENT PLANNING

Another lesson that was dramatically brought home to the public by the 1971 San Fernando earthquake was the need to take seismic considerations into account during land use planning. It has become apparent that a strictly engineering approach to earthquake hazards was insufficient to ensure the structural integrity of buildings or the safety of occupants. This led to the enactment of legislation requiring seismic safety elements, which provides for identification of hazardous areas and enactment of a system of policies and procedures to utilize this knowledge in the planning process. However, it should be recognized that the next severe Bay Area earthquake will provide engineers, geologists and seismologists with a vast amount of information of the performance of structure and various types of ground throughout the County. This geotechnical information should be used to guide reconstruction and redevelopment plans. (History offers numerous examples of communities that failed to redesign or change land uses in heavily-damaged areas because they did not have the plans and programs to carry out such redevelopment soon enough after a disaster.)

The Post-Earthquake Recovery and Redevelopment Advisory Group to the Legislature's Joint Committee on Seismic Safety has made a series of recommendations which suggest control mechanisms that can be instituted prior to an earthquake, and which will go into effect automatically in the post-earthquake period to provide a framework for reconstruction and redevelopment. The objectives of these recommendations are to minimize recovery problems and maximize the degree of seismic safety afforded to future generations inhabiting the stricken area. This panel of experts has recommended that counties and cities provide for post-disaster conditions in the General Plans, pointing out that at present General Plans do not provide for changes in circumstances that would follow a substantial disaster.

When compared with older established communities, Contra Costa County has relatively few areas in need of redevelopment or where existing land use would be considered obsolete. The majority of existing structures, particularly in the unincorporated areas, are family dwellings of frame construction that are generally able to withstand strong ground shaking without sustaining structural damage. Moreover, most apartments, public buildings and commercial buildings are modern structures which have had the benefit of the seismic design standards of the Uniform Building Code. However, there is an obvious need to ensure that proper consideration be given to changes in land use in areas which are heavily damaged by future earthquakes. Within the existing procedural framework,

the appropriateness of existing land use is periodically reviewed and updated. Generally these revisions of the General Plan are not made on a Countywide basis. Rather, they take the form of General Plan updates on a planning area or "community" basis. It is therefore strongly recommended that these periodic reviews take into account new scientific and engineering knowledge, particularly the localized information obtained from geologic and soils studies for projects proposed in the area. Further, the planning staff should develop contingency procedures for immediate updating of the General Plan in areas which are heavily damaged by a severe earthquake. Additionally, it is suggested that contingency redevelopment be considered in preparing or updating area plans.

COMMUNITY FACILITIES AND SEISMIC SAFETY

Emergency Response Facilities

Certain public and institutional services are needed immediately following an earthquake to aid the injured, prevent additional casualties, and protect property. These services are rendered through facilities that are termed "critical" or "essential" for seismic safety planning. These include major medical facilities (hospitals), police and fire stations, and emergency service headquarters and communications installations. If local emergency plans are to be put into effect, it is imperative that these facilities survive the earthquake and remain operative in the aftermath.

The experience elsewhere with critical facilities' performances during earthquakes has not been satisfactory. In the moderate 1971 San Fernando earthquake, for example, three hospitals near the epicenter were extensively damaged, garages collapsed on emergency vehicles, and emergency communications systems were put out of operation. Their failures had to be compensated for by essential services from outside facilities. Most of the damaged facility structures were built under modern building code standards. As a result of the San Fernando earthquake, hospitals were added to the facilities whose building plans receive state review, but these procedures will benefit only new construction.

Initial reconnaissance surveys in Contra Costa County (see Technical Background Report) indicate that some critical facilities are in older buildings, some are located very near the suspected locations of faults, and still others continue to be built without special construction and without geologic reports. The County's Emergency Operations Center is housed in a

hollow concrete block structure which meets only the minimum seismic design standards of the Uniform Building Code and, at least, its remote communications installations appear to be very susceptible to earthquake damage.

Other Community Facilities

Of the range of public and semi-public facilities (over 2,000 individual facilities were inventoried in Contra Costa County), the kinds beyond those discussed above have special earthquake significance: schools, public administration centers, and places of public assembly.

Schools have received the most public attention in the state since the Field Act was passed following the tragic collapse of an elementary school during the 1930 Long Beach earthquake. The 1933 Field Act required local school plans to be reviewed by the state. And, it required existing buildings to be brought up to standard or discontinued--something only now occurring in many communities. Unfortunately, the Field Act has not applied to all educational facilities (colleges, universities, and private schools are exempt), and it has evolved without its later provisions being made retroactive. School sites, as well as buildings, have been reviewed only since 1967, so some "safe" buildings may be located on earthquake faults or seismically poor ground. Nevertheless, although no post-1933 schools have been subjected to a major earthquake, none have been dangerously damaged by lesser earthquakes since the Field Act was passed.

Schools are often used for emergency operations centers during the post-earthquake and recovery periods.

Public administrative centers, such as city halls and county buildings, are also needed for disaster operations and recovery work. Places of public assembly, ranging from churches to auditoriums and stadiums, may subject large numbers of people to danger in the event of building failure during earthquakes. Yet, no special seismic consideration is routinely given to these facilities in their location, design, and construction.

Utility Facilities

Any prolonged disruption of utility service is dangerous to an urbanized society and its economy, but utilities (like transportation facilities) are highly vulnerable to earthquake damage.

Underground components of utility systems are often extensively damaged during substantial earthquakes. Pipelines for water, sewer service and gas; and even for electrical service and communications can be shattered in places. Damage to the water supply system is the most imminently serious because potable water is the commodity human beings need most regularly and because water is needed for fighting fires. Fire was responsible for much of the destruction of the 1906 San Francisco earthquake; fire that was able to burn unchecked for days because the City's broken mains could not bring water to its fire crews. Service can be restored in a matter of days or weeks by temporary installations but it may be many months before regular pipelines are repaired. Parts of Anchorage, Alaska, were still served by temporary above-ground lines more than a year after the 1964 Good Friday earthquake.

Above-ground transmission and distribution systems are also susceptible to earthquake damage, but they are usually easier and less expensive to restore than the underground installations.

Utility plants and stations are also subject to earthquake damage. One of the most severely damaged facilities in the 1971 San Fernando earthquake was the \$100 million Sylmar Converter Station, an electric system installation of regional importance.

The experience of other areas with utility installations during substantial earthquakes would doubtlessly have a counterpart in Contra Costa County. A review of the distribution of utility stations and lines relative to geologically hazardous features in the County shows that many cross faults, marshlands, and other areas that may be hazardous during earthquakes.

Transportation Facilities

Transportation facilities, especially the roads and streets of the arterial network are "critical" or "essential" facilities for responding to the effects of a substantial earthquake because they are necessary for the movement of emergency vehicles supplies, and evacuation transport. Later, they are necessary to accomplish reconstruction and restoration of the local economy. Airports, in enabling damage assessment reconnaissance flights to take place immediately after a disaster, and afterwards to accommodate the evacuation of casualties and supplies, are also initially important. Later, the full range of transportation facilities, including railroads, ports, and public transportation systems have roles to play in the recovery process.

Transportation systems are vulnerable to earthquakes. Road and streets are easily blocked, and are often buckled and broken, but emergency routes are readily improvised in time. The interchanges of freeways and similar installations (bridges and overpasses, for example) are often damaged but not readily restored. In the moderate 1971 San Fernando earthquake, forty-two bridge structures (mainly interchanges) were damaged and five collapsed. Railroad tracks are often so badly warped that they must be rebuilt. Even airports are susceptible to great damage; the control tower at the Anchorage, Alaska, International Airport fell during the 1964 earthquake there.

A major earthquake impacting Contra Costa County would be expected to cause widespread destruction to its transportation systems. The linear elements of these systems--roads, railroad tracks, and BART tracks--necessarily cross various earthquake faults as well as areas susceptible to ground failure. Landsliding from non-earthquake causes is a recurring problem that would be intensified by ground shaking. On the subject of ground failure, seven of the twelve freeway interchanges in the County are located in areas where a high liquefaction potential is suspected. Additionally, even freeway overpass structures sited on firm ground are susceptible to collapse from strong ground shaking. In some portions of the State, the California Department of Transportation (CALTRANS) has conducted special studies of existing freeway overpass structures and reinforced those which were found to be potentially hazardous under earthquake conditions. CALTRANS has not initiated such a study in this County and none is planned in the near future.

Some major highways and roads in the County could easily be closed, even to emergency vehicles, in the aftermath of a severe earthquake. According to CALTRANS, even if considerable damage is sustained to freeway structures, traffic can be restored on most highways (at least on a temporary basis) within hours or days. Obviously, the time required to make emergency repairs and/or reroute traffic will in part be a function of the areal extent of the impacted area. A great earthquake, such as the 1906 San Francisco earthquake, is capable of damaging roads throughout the Bay Region. It is probable that such an event would tax the earthquake response capabilities of all road agencies. It should be recognized, however, that CALTRANS has the capability of requesting maintenance assistance from any or all of the other ten state highway districts in California. According to CALTRANS such assistance, in the form of both men and equipment, is available on relatively short notice. The reconstruction of severely damaged overpasses would require weeks or months to complete.

CRITICAL INDUSTRIAL FACILITIES

There is great concern in seismic safety planning that an earthquake could trigger an industrial disaster. Up to now, earthquakes have caused some serious industrial installation failures, such as the rupturing of oil storage tanks in Alaska in the 1964 Anchorage earthquake, but these failures have not evolved into disasters. This history is fortunate but not particularly reassuring because lesser forces than earthquakes have triggered industrial disasters. One famous incident, the explosion of military ordinance in 1944, occurred in Port Chicago in Contra Costa County.

The industrial earthquake hazard includes the storage of potentially dangerous materials, disruption of critical industrial processes, and accidents involving potentially dangerous materials being loaded or transported.

The disaster potential from industrial causes irrespective of earthquakes is of particular concern to Contra Costa County because of the nature of many of its industries and because of its location in a region of high seismicity. The presence of petroleum and chemical industries, the "port" role in transshipping petroleum products and military explosives, and the presence of a major military explosives depot here, result in large quantities of potentially explosive, flammable, and poisonous materials being stored, processed, and transported in the County.

The mere presence of these materials and their processing locally does not automatically mean that an industrial (or military) disaster would result from a significant earthquake. Precautions being taken by industry and the military to avoid accidents and disasters are substantial and are considered generally effective.

The cause of concern regarding critical industrial facilities is that the seismic safety consideration given to the location of plants and storage areas and to the design and construction of industrial structures here is not up to date. Much new information on the nature of earthquakes and the design of structures--and this has been learned in the last two decades--is only now being applied to building codes and practices. As a result, the existing installations need to be evaluated in the light of current knowledge just as dams are being reviewed as a result of the very unsatisfactory performance of the lower Van Norman Reservoir Dam during the 1971 San Fernando earthquake. This kind of information is needed to assess the situation in Contra Costa County and it is not generally available.

SUMMARY

The purpose of the preceding discussion has been to make observations and preliminary estimates of the prevalence, location and degree of hazard posed by certain types of existing structures. And, it is intended to indicate the scope, direction and magnitude of work to be done subsequently to review individual facilities. It is apparent that the highest priority should be given to (a) critical structures (including industrial facilities and high occupation buildings) that are sited in hazardous fault zones, in areas subject to seismically-triggered flooding, and in marshland areas; (b) building types that are known to be hazardous ("Type III" construction, with unreinforced masonry walls using lime mortar and wood floors and roof); (c) older structures which have not had the benefit of seismic design provisions of the Uniform Building Code (the Riley Act was adopted by the California legislature after the Long Beach earthquake of 1933).

IMPLEMENTATION

PURPOSE

The Seismic Safety Element, like any general plan element, is to include a program for the implementation of its policies and recommendations. (In fact, a plan element should be prepared with its ultimate means of implementation in mind.) A general plan implementation program is characteristically generalized and is meant to guide the preparation of more specific and shorter-term programs, including departmental work priorities, the administration of laws, the provision of services, and the review of proposed structures or improvements.

These implementation recommendations are divided between two subject areas. The first is concerned with those aspects of Seismic Safety Element implementation that can be provided through the planning agency; the second, with programs of other agencies and jurisdictions that are pertinent to Contra Costa County's implementation efforts.

GENERAL PLAN RELATIONSHIPS

The addition of a Seismic Safety Element to a city or county general plan does not "take care of the subject". Instead, its adoption starts a process of adjusting the other plan elements to the findings and policies of the new element. Specialized elements such as this or the Noise or Safety Elements tend to be more important in influencing the more basic elements such as Land Use, Circulation, or Community Facilities/Utilities than in being used independently.

Further, the status of this Seismic Safety Element is that of an "initial" plan component which is intended to be filled out to a full or "final" version after a period of experience administering this first version and after additional information has been obtained.

In the following text, recommendations are made for, first, the adoption of the initial Seismic Safety Element; second, for the process and information needs of a full Seismic Safety Element; and, third, for the relationships between the other general plan elements and the Seismic Safety Element.

Adoption of the Initial Seismic Safety Element

The following steps were recommended in the Technical Background Report:

1. The Technical Background Report should be finalized and published as a staff document.

2. An initial Seismic Safety Element should be prepared and published, and taken to public hearing as an amendment (addition) to the County General Plan. This Element should rely heavily on the findings, policies, and recommendations of the Technical Background Report (which should be considered as a supplement to the Element).

The Technical Background Report has been published and this initial Seismic Safety Element has been adopted.

Development of a Final Seismic Safety Element

The initial Seismic Safety Element (with its Technical Background Report) is much closer to a "final" product than was first expected. Because of the extent of the work that has been done, follow-up work can proceed gradually for the next few years and concentrate on:

1. Producing and updating the implementation items identified herein.
2. Assimilating into the implementation process the information anticipated from other programs (e.g., inundation maps prepared by dam owners pursuant to S.B. 896).
3. Producing the specific subject studies identified in this report (e.g., slope stability map series).

The results of these, where appropriate, can be added to the Seismic Safety Element through selective amendments. Later the Seismic Safety Element itself can be comprehensively updated.

The process of updating and improving the Seismic Safety Element should utilize the County's "area" plan program as a vehicle. It has been a practice of the County to adopt a new subject element of the County General Plan on a countywide basis and then to update and detail the element in the course of updating and detailing its "area" plans. These plans are comprehensive (multiple element) efforts performed on an area basis and typically carried out with the participation of a local citizens' committee. With the advent of new state legislation, such as that requiring consistency between a government's general plan and its development ordinances, the County has initiated a program of area plan reviews that emphasize large planning areas to achieve frequent updatings, and which deal with both planning for the future development of unincorporated communities and the coordination of city-county planning efforts.

Information Required for "Final" Seismic Safety Element

This Plan has identified the kinds of information that are still needed in order to provide a full range of information for a "final" Seismic Safety Element. In summary, this information includes:

1. Detailed Geologic Information (and Administrative Map).
2. Administration Map Information. Fault Map, Ground Response Map, Liquefaction Map, Landslide Potential Map, Flooding Map (in connection with the Safety Element).
3. Structural Study. A study quantifying and locating the inventory of the County's structures relative to structural soundness (by use and construction) and seismic stress.
4. Information from studies expected to be performed by other agencies (e.g., highway interchange analyses).

Input to Other General Plan Elements

To a great extent, then, the Seismic Safety Element will be both implemented and updated through other parts and preparation programs of the County General Plan. Following are some of the ways the Seismic Safety Element should influence other state mandated general plan elements.*

1. Land Use Element. Most Seismic Safety Element recommendations either will not seriously affect the kinds of land uses or the densities of land use provided for in the General Plan (for example, performance standards for structures do not usually affect land use) or will function to provide detailing to development proposals of a scale that typically will not be discernible at the general plan level (such as not building on fault traces). However, certain large areas may be identified in the Seismic Safety Element which are, for example, subject to flooding, excessive shaking, or serious ground failure and, therefore, should be designated for open space or very low occupancy uses. In some areas the nature of seismic hazards might only restrict the location of high occupancy structures or critical facilities.

*The necessary generalness of these statements should not be interpreted as conflicting with more specific statements made elsewhere in this report.

2. **Circulation Element.** Most streets and other components of a transportation network follow land use decisions, so wise land use decisions will preclude most poor circulation decisions from a seismic safety standpoint. Nevertheless, direct attention must be given to the seismic stress performance of existing and future transportation structures and to their locations relative to seismic features (e.g., faults). In some cases, streets may be among the preferred alternative uses to be placed over inactive faults.
3. **Housing Element.** For the most part, the locational concerns of this element can be addressed in the Land Use Element. However, seismic safety considerations may affect the long range utility of a portion of the existing housing stock (i.e., its structural soundness), may accelerate the redevelopment of housing areas, and affect the cost of new housing. Seismic safety may have unequal impacts on the housing supplies of different social and economic groups because older, non-suburban buildings are more likely to be deficient.
4. **Open Space Element.** Seismic safety considerations which indicate that large areas should not be developed or accorded low development priorities affect both the Open Space and Land Use Elements. The open space potentials of localized seismic features, such as fault zones, may be mapped or covered by policy statements in the general plan, and guide the implementation process during project reviews or ordinance administration activities.
5. **Conservation Element.** A finding that a large area is seismically hazardous may be used in conjunction with conservation information to recommend the area for future resource protection usage (e.g., agriculture or watershed).
6. **Safety Element.** There is a subject overlap between the two elements with respect to those geologic hazards that are not entirely seismic in character but seismically induced, as well as precipitated by other causes (e.g., flooding, landslides).
7. **Scenic Highways and Noise Elements.** The recommendations of these elements have no direct relationships with seismic safety, but these may be affected by considerations already introduced in other elements.

In addition to the general plan elements mandated by the California Planning Law, there are other elements which may be utilized locally and which are significant in implementing the Seismic Safety Element; these include:

1. **Redevelopment Element.** Seismic conditions may indicate that certain areas are hazardous enough to warrant redevelopment, or that other areas may warrant changes of land use in the event they are substantially damaged by earthquakes (history indicates that the latter areas will be rebuilt as before unless redevelopment plans and programs are available). A Redevelopment Element, or equivalent recommendations in other parts of the general plan would provide an appropriate policy instrument to incorporate this kind of seismic safety information in the general plan. Unless or until Contra Costa County prepares a Redevelopment Element, this subject matter should be addressed in future "area" plan revisions.
2. **Community Facilities/Utilities Element(s).** Although the subject matter here is largely required by California Planning Law in connection with other elements, it is so basic to general plans that many cities and counties publish separate elements. Seismic safety information can be used in the preparation of this subject matter to indicate areas where certain facilities should not be built or where special design criteria need apply, or which existing facilities need to be phased out or rebuilt. Contra Costa County is preparing Community Facilities and Utilities Elements in conjunction with its "area" plans, and the material developed by the Technical Background Report can be utilized therein.
3. **Recreation Element.** This plan for parks and recreational facilities can utilize seismic safety information to an extent by including seismically hazardous areas in major parks and taking advantage of local seismic features for linear parks and similar facilities important at the local level. Contra Costa County has an adopted Recreation Element that is periodically updated.

PROJECT REVIEWS

The most expeditious results from this Seismic Safety Element program can be gained through the process of legal reviews for both public and private projects because they rely to a substantial extent on the project sponsor to respond to the findings of studies prepared for the project.

The basic recommendations here are that the Seismic Safety Element be utilized to its fullest in performing project reviews.

Project Review Programs

The main project review programs administered through the County Planning Department are:

1. Section 65401, Capital Projects Review. Section 65401 of the Government Code requires public agencies to submit yearly capital projects lists to the planning agency for review as to general plan conformance. This program is important because projects tend to be submitted in advance of detailed design, when they are most amenable to change. All projects can be reviewed in terms of the Seismic Safety Element's policies and recommendations.
2. Section 65402, Public Projects Reviews. Section 65402 requires that public and related agencies submit improvements project and land transfer proposals to the planning agency for advisory reviews relative to general plan conformance. Again, general plan conformance includes conformance to the Seismic Safety Element.
3. Clearinghouse Reviews. The County Planning Department processes most notices from the State, and mainly, the Regional Clearinghouse (ABAG) regarding the funding program applications of cities, districts, and other units of government. Already several external agencies have been advised that their proposed projects have not adequately or properly taken seismic risks into account. This is an important program for obtaining the adherence of non-County agency projects to the criteria of the County's Seismic Safety Element.
4. Environmental Impact Reports (EIR). This is the most effective of the project review programs because EIR's are written for most substantial projects and because they carefully evaluate environmental factors in relation to proposed land use (or a specific development plan). The raw information developed for the background report has been instrumental in changing the designs of a large number of projects by indicating the probable presence of geologic hazards, which were then confirmed by site investigations. The EIR process is expected to become even more effective when the administrative map series recommended by the Technical Background Report have been prepared.

Administrative Maps for Project Reviews

As a first step in the implementation of the Seismic Safety Element it is recommended that administrative map series' be developed. It should be recognized that the preparation of the administrative maps is largely a compilation of existing source materials. As such they will reflect the findings of the U.S. Geological Survey, the California Division of Mines and Geology, University studies and studies done for development projects in the County. When completed the maps will facilitate project reviews. Additionally, they can be used to aid in the identification of areas which require geologic investigations as a prerequisite for development. The map series which will be developed include the following:

1. Geology Map Set. To show latest mapping of County bedrock formations by the U.S. Geological Survey and California Division of Mines and Geology, classified for planning purposes by the County Planning Department.
2. Fault Map Set. To show earthquake faults, fault zones (including S.B. 520 information), and fault-related conditions. This is essentially a drafting effort.
3. Seismic Susceptibility Map Set. Shows areas subject to varying degrees of damage (seismic risk) susceptibility under earthquake conditions.
4. Liquefaction Map Set. Shows areas which may be subject to liquefaction under earthquake conditions.
5. Landslide Potential Map Set. Shows landslide-prone areas. As proposed the stability rating would rely on the "performance" of geologic units as a function of slope angle.
6. Flooding Map Set. Shows areas subject to levee failure, tsunami inundation, and dam failure. Recommended for preparation in connection with the Safety Element.

POLICY AND ADMINISTRATIVE DIRECTION

The act of the Board of Supervisors in adopting an element of the County General Plan implies certain policy positions relative to other units of government, and the giving of certain administrative directions to County departments. In the case of the Seismic Safety Element, it is recommended that these positions and directions be communicated formally as a means of

implementation. Among other considerations, this will facilitate implementation through the project review process. Specifically, the following actions should be taken:

1. Agencies of the federal government making physical improvements in Contra Costa County (Department of the Navy, etc.) or administering development programs (Department of Housing and Urban Development, etc.) should be requested to observe the County's seismic safety criteria and policies in carrying out their programs.
2. Similarly, appropriate agencies of the State should be requested to observe the County's seismic safety criteria and policies.
3. Regional agencies should be informed, especially the Regional Clearinghouse (ABAG).
4. Non-County public agencies and utilities making physical installations in the County should be informed.
5. The several cities in the County should be informed pursuant to State Planning Law.
6. County departments should be directed to comply with the Element.
7. Non-public associations and financing institutions involved in the development process should be informed of the Element's policies.

ORDINANCE ADMINISTRATION

As effective as advisory or disclosure project reviews may be, ultimately the force of law is needed to back up the review process or deal directly with some of the more difficult hazardous situations. The planning agency already administers several ordinances that regulate development and these are adaptable to the implementation of the Seismic Safety Element.

1. **Fault Zone Ordinance.** The Alquist-Priolo Special Studies Zones Act addresses a special aspect of seismic safety--the potential for surface fault displacement within designated Special Studies Zones. To date the state law has been administered as a matter of policy of the Board of Supervisors. Enacting an ordinance will provide guidance to applicants and others by formalizing the County's procedures for the implementation of the state law and establish a fee schedule to defray the costs of administering the law.

2. County Zoning Ordinance. The County Zoning Ordinance should be amended to provide specifically that seismic safety is a significant public purpose underlying the exercise of zoning requirements in Contra Costa County. The amendment should require geologic and other studies in areas found to be potentially hazardous. It should also refer to compliance with the general plan (meaning compliance with the Seismic Safety Element and other related subject matter) pursuant to Section 65800 of the State Planning Law.
3. County Subdivision Ordinance. The County Subdivision Ordinance should be amended in a manner similar to that recommended above for the zoning ordinance. It is noted that both the Governor's Earthquake Council and the Legislature's Joint Committee on Seismic Safety have recommended changes to the state statutes to make it clear that the furtherance of seismic safety is within the scope of "police power" purposes for zoning and subdivision regulations.
4. Specific Plans. Although the implementation instrument known as the specific plan, which is provided for in State Planning Law, is not technically an ordinance it functions as an ordinance by setting forth detailed requirements which development proposals must adhere to. It is recommended that future consideration be given to showing selected faults on Specific Plans because of the greater legal surety that would be obtained in administering these maps. The Specific Plan is an ideal instrument for this purpose but it does require highly accurate information for mapping that is not currently available.

OTHER PLANNING IMPLEMENTATION

Professional Services

It became evident during the preparation of the Seismic Safety Element that the services of the project's professional geologist were in great demand for other projects and by other agencies. Consequently, the initial draft of the Technical Background Report contained the recommendation that a permanent registered geologist be added to County staff and remarked in justification that the workload of environmental impact reports and area plan updating (among other projects) warranted the position. Shortly thereafter, the Alquist-Priolo Special Studies Zones Act became law, obliging the County to use the services of a registered geologist. The Technical Background Report recommendation was implemented in the 1974-75 fiscal year.

Seismic Safety Administrative Referral Panel

Because the administration of seismic safety requirements involves a wide range of technical knowledge and the exercise of judgment and interpretation, it would be desirable for Contra Costa County to create a panel of experts to assist in its administrative process. Such a panel could be modeled after the Bay Conservation and Development Commission's Engineering Criteria Review Board and include senior representatives of the geological, structural, engineering, and soils engineering professions in its composition. The panel could advise staff on Seismic Safety Element matters, but its primary function would be to serve as a referral body for appeals on administrative decisions on seismic safety matters made to regular planning appeal bodies such as the Zoning Administrator, Board of Appeals, and the Board of Supervisors. It might also serve as a referral panel for the administration of the building code.

Contra Costa County has an unusual resource in the number of its residents who are prominent in seismic safety fields. This panel would seek to enlist the services of some to benefit local development.

The responsibilities of such a panel would have to be carefully defined in view of its relationships to several planning functions, to several County agencies, and even to other units of government if the County contracts the services of its specialists. Therefore, it is recommended that the County Administrator with the assistance of the County Director of Planning and other staff at the Administrator's discretion, and in consultation with interested individuals and groups, to study the establishment of a Seismic Safety Administrative Review Panel, and to return its findings and recommendations to the Board by June 30, 1976.

City-County Cooperation

Since seismic features and seismic hazards exist over wide areas, and since most cities in Contra Costa County cannot justify their own registered geologists for general plan work and Alquist-Priolo Act administration, the draft Technical Background Report recommended that the County contract the services of a staff geologist to its cities. This recommendation began to be implemented when the Planning Geologist position was made permanent.

POST DISASTER GENERAL PLAN REVIEW

It should be a standing policy of the Board of Supervisors that the Planning Department will conduct a review of the County General Plan following an earthquake which produces damage in the County, with particular emphasis on the areas affected and the subjects in need of attention. The circumstances may warrant that a reconnaissance study be conducted and a more extensive program proposed to the legislative body.

In this connection, Contra Costa County should support (or initiate if necessary) actions by the state to make available planning and redevelopment grants under federal programs to local units of government impacted by disasters.

EMERGENCY OPERATING AGENCIES

The agencies listed below perform the functions of preparedness (pre-disaster planning and preparations), emergency operations (disaster response) and recovery. Their specialized services would be most evident during and immediately following a major earthquake.

County Office of Emergency Services

The County Office of Emergency Services is a division of the County Administrator's Office. It is responsible for the management of programs and the development of plans to enable the County to respond to any emergency or disaster caused by an act of man or an act of nature.

A major responsibility of the agency is planning for the full utilization of the total resources of the County under emergency or disaster conditions. The basic means for accomplishing this is the County Emergency Plan. This plan, which is approved by the State and adopted by the Board of Supervisors, establishes the County's Emergency Organization, specifies policies and general procedures, and assigns tasks and responsibilities to the participating agencies and organizations. An Earthquake Response Plan is included in the County Emergency Plan. Mutual aid, wherein one jurisdiction or agency will assist another jurisdiction whose response capabilities have been exceeded by disaster, is provided for in the plan.

The headquarters for emergency operations during a disaster is the County Emergency Operating Center (EOC) located near Glacier Drive and Highway 4 in Martinez. It is a communications center, an intelligence

collection center, the key point for coordination and control of all emergency activities, and is the receiving point for weather information, flood warnings, river bulletins, fire and police information, and earthquake and tsunami alerts and warnings. The facility also serves as the day-by-day offices for the Office of Emergency Services and the Communications Division of the Sheriff's Office.

The County Office of Emergency Services maintains a close working relationship with state agencies, federal agencies, other counties, and with emergency resource agencies from the private sector. This helps to ensure compatibility and uniformity of plans and facilitates coordination of emergency operations, particularly under major disaster conditions.

Discussion with the Office of Emergency Services indicate that the following steps would significantly improve the County's capabilities to respond to a severe earthquake:

1. **Supporting Plans.** Although the County has an approved Emergency Plan, a number of supporting plans have not been prepared yet, and several adopted supporting plans were prepared several years ago and are in need of review and updating. Some of the supporting plans which require updating pertain to the earthquake response capabilities of the County.

Detailed service supporting plans should be prepared for those agencies that do not have them (Logistics, Transportation, Welfare and Shelter, and Operational Facilities). Plan preparation should be done in cooperation with the County Office of Emergency Services personnel. Additionally, all plans should be reviewed or revised at two year intervals.

2. **Training of Personnel.** In an emergency situation, coordination and cooperation of all agencies having a disaster response function is critical to success. This requires training activities which familiarize key personnel with plans and procedures, and workshops to familiarize personnel with the responsibilities of their organizations during an emergency situation. Additionally, key personnel from each unit should be exposed to an earthquake exercise similar to the 1971 Command Post Exercise conducted by the County Office of Emergency Services.
3. **Emergency Operations Center.** The County Emergency Operations Center (EOC) does not have sufficient space for full-scale emergency operations. In any major disaster, the Emergency Operations Center must be of adequate size to properly accommodate not only necessary County personnel,

but numerous representatives from supporting military units, and from other Federal and State agencies. To enable all coordinating personnel to function at peak efficiency, they should be located within the Emergency Operation Center in very close proximity to one another, preferably in a large operations room with communications facilities adjacent.

The present facility is housed in an unreinforced hollow concrete block structure of questionable seismic response characteristics. Moreover, it does not have adequate space to properly accommodate the number of personnel required for full scale emergency operations. An adequate facility which can withstand the tremendous forces generated by a major earthquake is absolutely essential if, under those conditions, the needs of the public are to be served.

4. Communications Study. In connection with Emergency Operations Center needs, a study should be made of the seismic survivability of the County's communications systems. This plan has previously noted that components of the communications system are susceptible to earthquake damage.

California Office of Emergency Services

In the context of the Seismic Safety Element, it should be noted that in a major disaster the resources of even a well prepared local jurisdiction may be overwhelmed. For these reasons the State of California has assumed considerable responsibility for comprehensive natural disaster preparedness planning and disaster assistance in a declared emergency.

The State Office of Emergency Services has responsibility for comprehensive emergency preparedness planning at the State level. It prepares the California Emergency Plan, which establishes a statewide emergency organization and coordinates the emergency activities of all agencies. At present the State Office of Emergency Services is developing an Earthquake Response Plan. An equally important function of the State Office of Emergency Services is to give a technical and administrative review to the emergency plans prepared by local jurisdictions. One purpose of that review is to ensure a coordinated and efficient response to an emergency situation, such as a severe earthquake, by all agencies and governments. The plans prepared by local governments must mesh together to prevent gaps or inconsistencies. Similarly, local plans and State plans should compliment

one another and be compatible with Federal plans to establish a "chain of command" which enables the smallest city to call upon the resources of the entire nation through mutual aid. Additionally, the State Office of Emergency Services recommends working relationships between local governments and relief organizations, such as the American National Red Cross.

The State Earthquake Plan has not been finalized. Hopefully, this plan will be finalized and published during the next year.

Basically, coordination between emergency planning at the local level and state level exists now and is on-going. No additional implementation measures are proposed at this time.

Federal Disaster Assistance Administration

The Act of Congress constituting the Federal Disaster Assistance Administration provides for the mobilizing of federal personnel and resources immediately upon the declaration of a major disaster. The purpose of the federal program is to supplement local and state programs, thus improving their capability of adequately responding to emergencies, such as those which are created by damaging earthquakes.

With respect to disaster planning, the role of the federal government has been to provide financial incentives to local and state government to develop comprehensive plans and practical programs. At present, for example, approximately fifty percent of the operating budget of the Contra Costa County Office of Emergency Services is defrayed by federal matching funds.

The Disaster Relief Act of 1974 provides for appointment of a Federal Coordinating Officer (FCO) immediately upon declaration of a major disaster by the President. The FCO is responsible for determining the types of federal relief most urgently needed and coordinating the procurement and allocation thereof with the State Coordinating Officer. He will also coordinate the activities of the Red Cross and other relief or disaster assistance organizations which are national in their scope and that agree to act and operate under his advice or direction.

A working relationship exists, largely through the State, between the County Office of Emergency Services and the Federal Disaster Assistance Administration. No additional implementation measures are proposed at this time.

American National Red Cross

The Act of Congress constituting the American Red Cross charter requires the Red Cross to undertake relief activities to mitigate suffering caused by disasters and obligates the Red Cross to develop and carry out measures to prevent such suffering. Through a program of disaster preparedness by Red Cross chapters, the American Red Cross provides disaster victims with food, clothing, shelter, first aid and supplemental medical care. The assistance provided by the Red Cross includes emergency mass care, emergency service on an individual family basis and post disaster aid for recovery to families.

Because the American Red Cross is financed by voluntary contributions, the amount of assistance it can provide independently is limited by the availability of volunteers and supplies. However, federal and state agencies may distribute, through the Red Cross, medicine, food or other consumables and may render other emergency assistance. Red Cross aid is not dependent upon a Presidential declaration of a major disaster but can be provided regardless of the size of the catastrophe, the number of people involved, or the commitments of any other voluntary or governmental agency.

The County Office of Emergency Services is in continual contact with the local chapters of the Red Cross. A close working relationship also exists between the County Social Service Department and local Red Cross chapters. These organizations are attempting to coordinate their efforts to aid disaster victims following a major earthquake or other catastrophe.

A direct working relationship exists between the County Office of Emergency Services (as well as other County agencies) and local chapters of the American Red Cross. The County should continue to coordinate and cooperate with the Red Cross on problems of mutual interest. No additional implementation measures are proposed at this time.

SCIENTIFIC PROGRAMS

This Seismic Safety Element has stressed the inadequacies in the seismic data and geological mapping available for Contra Costa County. These inadequacies need to be overcome if the County is to take proper seismic safety precautions in proceeding with building and development. For the most part, the needed information is produced through regular programs of agencies of other units of government.

The purpose of this section is to review the principal scientific programs which provide information on the seismicity and geology of the County, to review the informational needs of the County and to recommend actions to fulfill these needs.

Seismic Monitoring

The systematic monitoring of seismic activity is necessary to establish indices of risk and exposure to earthquakes of various magnitudes, durations, and accelerative force, and to verify and locate active earthquake faults.

Monitoring by General Purpose Seismographs. As noted previously, since 1934 the University of California has been monitoring the seismicity of the Bay Area. Their network of general purpose seismographs, which are capable of identifying earthquakes as small as approximately 2.0 on the Richter Scale, have recorded nearly six hundred earthquakes with epicenters in or immediately adjacent to Contra Costa County during this period. Because of the sparse number of instruments, epicenter locations are subject to varying degrees of error. In general, the more recent earthquake events and the stronger events tend to be the most accurately located, and even these events may be mislocated by a mile or more. In addition to providing information for calculating the location of epicenters, seismogram records yield data on earthquake magnitude, focal depth and type of fault slip which gave rise to the earthquake shocks. The seismograms also record the physical characteristics of the ground motion itself including accelerations, velocities, period, displacements and cycles of seismic loading.

Microseismic Event Monitoring. Since 1969 the National Center for Earthquake Research (NCER) has been monitoring microseismic events in the San Francisco Bay Area using a network of special-purpose telemetered seismographs which record continuously, transmitting data directly to the Center's office in Menlo Park for processing and interpretation. Their microseismic network provides improved information for locating earthquake epicenters as well as being able to detect very small magnitude earthquakes. These are important since they allow for a more precise identification of active seismic zones.

During 1970 alone over a hundred earthquake epicenters were detected in those portions of the County being monitored (western and central Contra Costa County). Systematic patterns are beginning to emerge which delineate linear seismic zones. As previously mentioned, these are zones where slippages are occurring at depth (minor faulting taking place in the subsurface) and thus are "red flags" identifying potentially active faults.

Microseismic monitoring in Contra Costa County dates from only 1970. The network has been monitoring seismic events ranging in magnitude from 0.5 to greater than 4.0. During the 1973-74 fiscal year the National Center for Earthquake Research began to expand its network into eastern Contra Costa County by establishing new stations east of the Diablo Range. One station was sited near Antioch and another station near Altamont in Alameda County. Additionally, the Center expects to locate a seismic station near San Pablo to provide better control over the location of earthquake epicenters in western Contra Costa County and adjacent areas.

With respect to the existing programs it should be recognized that the siting of stations must be based on scientific considerations. However, it is apparent that several active seismic zones bisect the County and that the "crustal model" for this area is in need of refinement. It would be desirable for the County to cooperate with the National Center for Earthquake Research in their efforts to establish additional stations in the County and, if feasible, engage in a cooperative study with the National Center for Earthquake Research to modify the crustal model. These steps would significantly improve the precision with which epicenters are computed.

Strong-Motion Programs. A strong-motion seismograph (also called accelerograph) is an instrument designed to record the stronger vibrations caused by earthquakes. It records only when a strong earthquake triggers the instrument. The records are used in designing structures to be earthquake resistant.

Strong-motion instruments were not developed until 1932 and as recently as 1971 there were only five hundred instruments in California, and the majority of these accelerographs were sited in tall buildings in the City of Los Angeles. Only four instruments were located in Contra Costa County as recent as January, 1974. Recognizing the need for instruments in geographic areas not yet covered; on representative soil and rock sites throughout the state; and on a broad group of representative buildings and structures, the 1971 California Legislature established a statewide strong-motion seismograph instrumentation program. It was funded by a very small percent assessment on estimated building costs as determined by the issuance of building permits. (For administrative economy, the County appropriates its fee to the state and sets its permit fee to indirectly cover costs.)

The California Division of Mines and Geology administers the State program with advice from an Advisory Board appointed by the State Geologist. It is carried out in cooperation with other government agencies, both State

and federal. All State instruments are integrated into the Strong-Motion Network of the Seismic Engineering Branch of the U.S. Geological Survey.

As of July, 1975 only three state instruments had been installed in the County. The instruments have been sited in the Antioch School District Service Building at 5th and G Streets in Antioch, in the Eastman Kodak Building in San Ramon Village and in Briones Dam. The Site Selection Committee has authorized the siting of another two instruments in the Danville area. One of these instruments will be established on an alluvial site and the remaining station will be sited on bedrock. The Site Selection Committee has also authorized an array of four instruments which will extend from Seal Rock through San Francisco and across the Hayward fault. It is probable that at least one of these stations will be located in the County.

The County should actively encourage studies which will provide the basic data needed to assess or reduce earthquake risk. With respect to strong-motion instrumentation, the County should urge the State to assign a high priority to establishing instruments in critical areas, such as the Delta Islands and the levees which protect them. Such data would provide a more reliable basis for predicting ground response and evaluating seismic risk in monitored areas.

Crustal Movement Programs

Seismographs and accelerographs record seismic events but another kind of program that is needed is one to monitor the cumulative effects of the movements of rupture and creep in the earth's crust.

It was previously noted that these movements continue to reshape the landscape of Contra Costa County, and eventually enough may be known about them to allow a mathematical model to be made of the shifts occurring in the Bay Area which will enable scientists to predict earthquakes. There is already evidence that unusual deformation takes place in the earth's crust prior to the highly damaging shallow focus earthquakes, such as those which occur in California.

There are several public agencies that conduct crustal movement studies through advanced forms of surveying or instrumentation in the Bay Area. These include the U.S. Geological Survey, and agencies recently assigned to it, and the California Division of Mines and Geology.

The earliest instrumental measurement of crustal deformation along active faults was provided by geodetic triangulation. Within the Bay Area, retriangulation following the 1906 San Francisco earthquake documented the right-lateral offset which had occurred on the San Andreas fault. In the late 1950's precise trilateration surveying methods and instruments were developed which facilitate more accurate measurement of crustal movement. And more recently instruments have been developed which make it possible to continuously monitor fault slip, strain, and tilt. Table 10 summarizes crustal movement programs and instruments within the County; it also includes comments on observations made to date.

County agencies should be aware of these programs and the significance of the observations made to date. While seismologists are unable to predict earthquakes at present, the information gathered to date should be considered in the design and location of man-made structures.

In order to more accurately assess the movement potential of active faults in the County, such as the Concord fault, the County should encourage and cooperate with the U.S. Geological Survey and California Division of Mines and Geology in efforts to establish a network of survey lines across such faults at critical locations. In the event that these agencies are unable to conduct such a program in a reasonable time, the County should solicit cooperation from affected cities and public utilities to install its own network.

MAPPING PROGRAMS

This Element has stressed the need for additional detailed geologic mapping in order for the County to round out its Seismic Safety Element and its (proposed) seismic safety administration maps. In summary, these are the mapping programs involved:

1. Special Studies Zones Maps (California Division of Mines and Geology). This mapping which is carried out by the State Geologist for the administration of the Alquist-Priolo Special Studies Zones Act (S.B. 520) shows active faults and associated special studies zones. Currently, the mapping is far from complete; for example, it relied largely on published mapping and initially did not include major faults in central or eastern Contra Costa County.

This mapping is of such importance to the administration of the Alquist-Priolo Special Studies Zones Act that the County should at least urge

TABLE 10 SUMMARY, CRUSTAL MOVEMENT PROGRAMS AND INSTRUMENTATION,
CONTRA COSTA COUNTY

SURVEY METHOD OR INSTRUMENT	LOCALITY: SITE NAME	FAULTS CROSSED	OBSERVATION DATES	AGENCY	COMMENTS
U.S.G.S. Program Large Triangulation Nets (Geodetic) (Process of determining the pre- cise position of monuments in a trigonometric survey.)	San Francisco Bay Area	Crosses all active faults	1882, 1902, 1922, 1945, 1951, 1957 1963, 1969	NOS	Lines cross all active faults; measurements indicate 5 to 6 cm/year of right-lateral displacement between Mt. Diablo and the San Francisco peninsula. Evidence of fault slip inconclusive.
	Alameda County: Camp Parks	Calaveras and Pleasanton	1969	NOS	
Small Triangulation Nets (Fault Crossings) (see above)	El Cerrito: Mar	Hayward	1966, 1968, 1970	NOS	Creep rate of Hayward fault 0.5 to 0.7 cm/year (right lateral offset)
	U.C.B. Stadium	Hayward	1966, 1967, 1969	NOS	
	Pleasanton: Camp Parks	Calaveras and Pleasanton	1964, 1965, 1969	NOS	
Tiltmeters (A device sensitive to changes in slope of the ground surface)	Berkeley: Berkeley	-----	Installed 1970	NCER	Anomalous tilt event observed in Berkeley 29 hours prior to onset of the 1970 Danville earthquake swarm.
Creepmeters (Continuously recording instru- ment which measures the change of distance between two monuments)	San Pablo: El Portal School	Hayward	Installed 1971	SEB	Creep rate on Hayward fault 0.5 to 0.7 cm/year (right-lateral offset)
Alignment Array (A line of monuments set across a fault)	San Pablo: San Pablo	Hayward	Installed 1968	SEB	Creep rate on Hayward fault 0.5 to 0.7 cm/year (right-lateral offset)
	El Cerrito: Country Club Drive	Hayward	observed annually	SEB	
Trilateration (Surveying method utilizing a laser beam; accuracy is about 10 times greater than that of a first order triangulation survey)	Mt. Diablo	Network crosses all active faults		CDMG	Lines across Hayward fault indicate right- lateral movement 1-1/2 cm/yr. In Gilroy area, lines across combined Calaveras, Sargent, and San Andreas faults indicate 2-1/2 cm/yr movement in right-lateral sense.

*Key to Agency Abbreviations

NOS = National Ocean Survey (NOAA)

NCER = National Center for Earthquake Research (U.S.G.S.)

SEB = Seismic Engineering Branch (U.S.G.S.)

CDMG = California Division of Mines and Geology

the State Legislature to appropriate additional funds to accelerate this mapping program; if necessary, the County should join with its cities to help finance a fault mapping project by the Division of Mines and Geology to ensure the timely preparation of these maps.

2. Bedrock Geology (U.S. Geological Survey). As previously noted, the U.S.G.S. is preparing a set of basic geology maps for this area as part of the San Francisco Bay Region Environment and Resources Planning Study at the scale of 1:62,500. The coverage for the eastern part of Contra Costa County has already been published. No additional County action is needed.
3. Surficial Deposits Maps (U.S. Geological Survey). The U.S.G.S. is also preparing a map series which show the distribution of surficial deposits in the County at a scale of 1:62,500. It is anticipated that these maps will be published in the next year. No additional County action is needed.

Although it is mentioned briefly in an earlier section of this report, it should be reemphasized that the next severe earthquake to impact this area will provide geologists and engineers with a vast amount of critical information on the seismic response characteristics of geologic units and man-made structures in this County. To facilitate proper consideration of these factors into land use, facilities and service planning during the post-earthquake period, the County should urge the State to undertake appropriate mapping and engineering studies as soon as practicable after any damaging earthquake. To be fully effective at least preliminary results of these studies should be available no more than ninety days after the earthquake.

AID, GRANT, AND INSURANCE PROGRAMS

In the event of a major earthquake, or other disaster, Contra Costa County government, firms, and residents most likely would be the recipients of grants and aid from the federal government to facilitate recovery. Additionally, individuals and firms probably would be assisted by tax write-offs on portions of their damages under both state and federal tax laws. In the future, however, it is expected that more reliance will have to be placed on insurance programs, and taxes may be used in a positive manner to obtain seismic protection.

Aid and Grant Programs

Originally, public aids for recovery to disaster areas were given on an ad hoc basis, usually by state governments, and usually for particular facilities projects. By the early 1970's the situation had evolved to the extent that the federal government had become the near exclusive source of financial aid for recovery and not only government but individuals and firms had become eligible to receive it. Public Law 93-288, the Disaster Relief Act of 1974, enables assistance outlined in Table 11.

TABLE 11 SUMMARY OF POST DISASTER PROGRAMS WHICH MAY
BE AVAILABLE FOLLOWING A SEVERE EARTHQUAKE

<u>Administrator</u>	<u>Assistance</u>
Federal Disaster Assistance Administration (FDAA)	Funds to state and local governments to restore public facilities and to accom- plish the emergency repairs within them. Grants, up to \$5000, to individuals that can prove disaster related need over and above the other assistance provided. Emergency assistance to individuals in- cluding but not limited to transportation, mass care, temporary housing, relocation costs, food stamps, and unemployment compensation.
American National Red Cross and other philanthropic organizations	Immediate needs, i.e., temporary shelter, clothing, food, and medical care. Grants and/or loans to restore and/or re- place the individuals' pre-disaster essen- tial facilities.

Aids to Governments. Public Law 93-288, the Disaster Relief Act of 1974, is the basis for Federal Disaster Assistance to states and local governments in a declared disaster. It provides federal contributions for emergency repairs, and restoration to pre-disaster standards, of public facilities including those of parks and recreation districts. Another provision of this Act supports development of state and local emergency organizations and those plans necessary to cope with major disasters.

The Act provides grants to local governments to compensate for substantial loss of property tax revenue. Because a local government is dependent on sources of tax income that are badly impacted by disasters, such as the property tax, it finds itself having to maximize its services while it is receiving minimum revenues. Grants made under this section of the law may be made for the tax year in which the disaster occurs and each of the following two years. Provisions for assistance in advance of an imminent major disaster are included in the Act.

With respect to capital facilities, the Federal program probably will be needed in the future unless a satisfactory insurance program is devised, and its continuation should be supported by Contra Costa County. The Federal government, however, should reasonably be assured that local public installations are not being built in hazardous areas and that structures are designed to withstand the stresses to which they may be exposed.

Aids to Firms. The principal federal program that is available to business following a disaster is administered by the Small Business Administration. Major provisions of the disaster loan authorities of the Small Business Administration (SBA) include the following:

1. SBA is authorized to provide loans without regard to whether private sources are available for such loans (Public Law 93-288 fixes the maximum allowable interest rate on such loans at six percent).
2. SBA loans may not be denied on the basis of the age of the applicant.
3. The dollar value of SBA loans may not exceed the current repair or replacement cost of the disaster loss.
4. SBA is authorized to provide for refinancing of mortgages and loans.
5. In a Presidentially declared "major disaster" the borrower may cancel the principal of a loan in excess of \$500, up to \$2500.

Aids to Individuals. Public Law 93-288 provides short-to-intermediate term aids ranging from temporary housing to unemployment assistance. The Small Business Administration loan program provides rebuilding loans to individual property owners impacted by a disaster and further provides a "forgiveness" (virtual grant) feature to those considered as hardship cases.

Federal programs for individual aid that make provisions for expanded use of existing aid programs are valuable and needed assists to both individuals and the local economics of areas impacted by disasters. They should be encouraged by Contra Costa County.

The present program of the Small Business Administration loans to individual property owners has been an excessively expensive program that has benefited those who experienced little property damage comparatively more than those who suffered serious losses. The SBA mechanism has proven to be too small to process loan requests rapidly under widespread disaster conditions (e.g., San Francisco earthquake area). The forgiveness feature is subject to misuse. Contra Costa County should support the replacement of this program. Probably, a combination of public loan supports through private lending institutions and mandatory earthquake insurance would prove more workable.

Insurance

Because of rising costs in providing aids to disaster areas, state and federal governments are increasingly looking to insurance as a future mainstay to recovery. The 1973 Federal Flood Insurance Act, which requires insurance and land use controls in flood-prone areas, is a step in that direction. Earthquake insurance is widely available from the private insurance industry at rates which are affordable to most people. However, few properties in California are covered by earthquake insurance. The likely reason the public is not generally purchasing this insurance is because they consider the probability of damage in any given year to be too low to insure against, and the premiums too high (most people would probably use the same rationale to refuse fire insurance, were it not required by lending institutions). Some insurance companies have hesitated to offer or promote the sale of earthquake insurance because of their inability to accumulate reserves to cover the probability of large-loss events.

The Governor's Earthquake Council and the Legislative's Joint Committee on Seismic Safety both have encouraged, essentially, that earthquake insurance be required much as fire insurance is now obligatory for new residential property loans and urged as part of comprehensive insurance packages to cover remaining residences. The insurance industry is also considering this position. At the present time, proposals under discussion are for this kind of insurance to be extended to, say, one-to-four unit residential structures. The insuring of larger residential structures and commercial or industrial buildings against earthquake damage is considered to be a more complex problem and one which may entail federal reinsurance of companies because of the concentration of risks and the limitations on companies' accumulating large reserves.

It should also be recognized that "universal" disaster insurance covering floods, tornados, hurricanes, and other causes is being discussed elsewhere in the United States. There is some speculation within the insurance industry that the federal government may take the initiative in offering this kind of insurance if the industry does not respond.

Depending on the appropriateness of the particular proposals, Contra Costa County should encourage state and federal efforts to have citizens insure their properties against disasters. Earthquake insurance is needed, but all-risk insurance covering flooding and land failure is preferable. In some parts of Contra Costa County, disaster insurance may become a prerequisite to development.

Taxation Programs

It is beyond the scope of this Seismic Safety Element to cover the complex provisions of state and federal tax law as they pertain to the write-off of damages suffered through earthquakes and other disasters. Suffice it to say that these provisions exist and that they are usually reasonable. There are, however, two aspects of taxation that warrant consideration and recommendation for County action.

The first area of concern relates to the assessment of property in seismically hazardous areas. As has previously been mentioned, the state law requiring a Seismic Safety Element places with local government the responsibility for establishing effective land use controls which guide development in a direction which is appropriate and beneficial to the public, recognizing all relevant factors. However, the taxing powers of government can actually encourage urbanization of a hazardous area by assessing property at a rate which makes agriculture and other types of open space land use uneconomical.

A second area of concern to a Seismic Safety Element is the role of the taxing powers of government in promoting seismic safety improvements to existing structures. A tax incentive program could reduce seismic risks at a relatively low cost to taxpayers. At present seismic safety improvements, although they may not increase property values, are taxed like any other improvement. An adequate tax incentive program, designed to upgrade unsafe structures, would substantially reduce losses during the next severe earthquake. It should be emphasized that the cost of such improvements is not solely an economic question since lives as well as property are in danger.

Depending on the appropriateness of the particular proposal, Contra Costa County should support legislation to consider geologic hazards in the assessment of property and the reassessment of property following a disaster. The former was the subject of the successful Proposition 4 in the June 1974 General Election. With regard to the seismic safety of existing structures, Contra Costa County should study the support of legislation for a one-time tax write-off of the value of improvements made to bring existing structures up to earthquake standards. The application of such legislation would follow the adoption of definitive standards of structural safety.

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APPENDIX

APPENDIX A: THE APPENDIX

The Appendix is a collection of documents that are related to the main text. It includes a list of references, a list of figures, and a list of tables. The Appendix is organized into sections, each of which contains a list of documents. The documents are listed in chronological order, with the earliest documents at the top of each section. The Appendix is a valuable resource for anyone who is interested in the history of the subject.

APPENDIX B: THE APPENDIX

APPENDIX

APPENDIX

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1870
The first of the series of papers in the collection of the
Library of the University of California, Berkeley, is a
manuscript of the first volume of the "History of the
University of California," written by the Rev. John
S. Henshaw, D.D., and published in 1870. The
manuscript is in the possession of the University of
California, Berkeley, and is a valuable addition to the
collection of the Library of the University of California,
Berkeley.

APPENDIX

TECHNICAL BACKGROUND REPORT

FINDINGS, POLICIES, AND RECOMMENDATIONS

The Seismic Safety Element is based on its Technical Background Report (see page 3). Chapters in that report concluded with statements of their findings and proposed policies and recommendations. These are included as part of this plan to add detail to the preceding text. A minimum of editing has been performed to adapt the wording of some statement to their present context and to include revisions that were made in the course of reviewing and adopting the Seismic Safety Element.

GENERAL SEISMICITY

Findings

1. Earthquakes and faulting are a response of rocks to stresses which are set up within them. During the fault movements, strain energy that has accumulated in the earth's crust is converted into earthquake producing elastic wave energy which radiates from the moving fault plane. The resulting ground motion is responsible for the majority of earthquake damage.
2. Worldwide, the U.S. Coastal and Geodetic Survey reports approximately five thousand earthquakes per year. Annually, California can expect to experience more than five hundred earthquakes which will be strong enough to be recorded by general purpose seismographs. It should be recognized that the monitoring of earthquakes in California is much better than the world generally. However, most seismologists believe that approximately one to three percent of the world's earthquakes occur in California.
3. The great majority of earthquakes are not dangerous to life or property either because they occur in sparsely populated areas or because they are small earthquakes which release relatively small amounts of energy. However, where urban areas are located in regions of high seismicity, damaging earthquakes are expectable if not completely predictable events. For example, the San Francisco Bay Region has been impacted by more than ten severe earthquakes during historic time.

4. Substantial earthquakes are typically followed by aftershocks. Some aftershocks can be highly damaging, particularly when centered in densely populated areas or in areas where man-made structures or the ground has been weakened by the main earthquake.

Mankind has the capability, through wise land use planning--taking into account the materials and forces of the earth itself--to mitigate the destructiveness of even the most severe earthquakes.

Policy

1. In an area of high seismicity, planning, development, and building should incorporate scientific and engineering knowledge of earthquake causes and the response of ground and structures to earthquake forces.

Recommendation

1. All levels of government responsible for guiding and regulating development and building in seismically active areas should adopt plans, policies and procedures, and enact legislation, to ensure the application of scientific and engineering knowledge to the protection of lives and property.

EARTHQUAKE CAUSES

Findings

1. The "Plate Tectonic Theory", which holds that the earth's crust is composed of lithospheric "plates" that are systematically shifting and changing form over a semi-plastic under-surface, for the first time satisfactorily accounts for earthquakes and their distribution.
2. No place on earth is totally safe from earthquakes, but most cluster in narrow, continuous belts of high seismic activity that coincide with the boundaries of lithospheric plates.
3. According to the plate tectonic theory, the San Andreas fault is a major transform fault which forms the boundary between two major lithospheric plates. That portion of California which lies west of the San Andreas is part of the Pacific Plate; the area east of the San Andreas is part of the Americas Plate.

4. The actively spreading East Pacific Rise causes stress to accumulate in rocks along the San Andreas fault. When the stored energy equals the resistance of these rocks to shearing, fault movement occurs on the San Andreas fault system and California has another earthquake.

Policy

1. In an area susceptible to high seismic activity public policy should recognize that a severe earthquake hazard exists and reflect this knowledge in their programs.

Recommendation

1. All levels of government functioning in areas susceptible to high seismic activity should direct their agencies to give appropriate attention to seismic safety in the creation and execution of their programs, and cooperate with one another to ensure the effectiveness of their efforts.

EARTHQUAKE MEASUREMENT

Findings

1. During an earthquake, strain energy which has been stored in the crust is converted into elastic wave energy which radiates away from the moving fault plane and produces three kinds of waves that travel through the earth in different ways. Instruments can plot both the location and magnitude of an earthquake by measuring the characteristics of recorded wave forms and the time intervals that they are received.
2. Although three types of waves are transmitted through the earth's crust, most or all of the damage ascribed to ground shaking is attributable to "surface waves". These high amplitude waves are capable of producing severe damage over a broad area, depending on the magnitude of the earthquake, local ground conditions, and other factors.
3. Two kinds of systems are universally used to describe earthquakes: the objective mathematically-precise "magnitude" scale (Richter Scale) necessary for instrumental measurement and scientific work; and, the more subjective "intensity" scale (Modified Mercalli, or M.M. Scale) that describes locally perceived effects.

4. Three kinds of instrumentation systems are needed to document seismic activity: General Purpose Seismographs to record significant earthquakes over wide areas; microseismic instruments to measure small tremors locally (and locate faults); and strong-motion seismographs to record the detailed local characteristics of strong shocks.
5. Seismograph records are used for many purposes, such as determining the location of the epicenter, depth of the focus and characteristics of ground motion. Additionally seismograph records can be used to locate active seismic zones.

Policy

1. In seismically active areas, it should be public policy to obtain an operational system of seismic recording instruments (including general purpose seismographs, microseismic instruments, and strong-motion seismographs) and a related information transmittal system.

Recommendation

1. Governments in seismically-active areas should individually and cooperatively work to secure seismic instrumentation and transmittal systems.

EARTHQUAKE GEOLOGIC EFFECTS

GENERAL

Finding

1. The major geologic effects of earthquakes are ground shaking and ground failure. Severe earthquakes are characteristically accompanied by surface faulting; less commonly by tsunamis and seiches. Flooding may also be triggered by dam or levee failure.

Policy

1. Public policy regarding seismic safety should consider each of the geologic hazards affecting the area.

Recommendation

1. Governments in seismically active area should individually and

cooperatively work to identify and evaluate their geologic hazards, and direct their agencies to consider each in their programs.

FAULTS AND FAULT DISPLACEMENT

Findings

1. A fault is a fracture in the earth's crust along which the two sides have moved relative to each other. It should be recognized that all active faults have a high probability of future movement. With regard to planning and development two aspects of fault displacement should be considered: (a) the effects that sudden movement along faults may have on structures built across their traces, and (b) the relatively slow effects of fault creep on structures built across their traces.
2. Faults vary considerably in their length and significance, from those which are major crustal features having regional importance to minor faults having only local significance. A major fault system may be hundreds or thousands of miles long and displace rocks on opposite sides of the fault by more than a hundred miles. A minor fault may have an extent of a few miles or less and the total offset may be tens of feet or less. It should be recognized that either fault can pose a threat to structures sited astride the fault trace.
3. Fault displacement involves forces so great that the only means of limiting damage to man-made structures is to avoid the traces of active faults, unless structures can be designed to accommodate the expected displacement. Any movement beneath a structure in excess of an inch or two could have catastrophic effects on the structure, depending on its design and construction.
4. Faults which have had surface displacement within Holocene time (about the last 11,000 years) may be considered active. Evidence of active faulting may include any of the following: (1) historic earthquake accompanied by surface faulting, (2) tectonic creep, and (3) fault offset involving deposits of known or inferred Holocene age.
5. Faults which have had surface displacement within the Quaternary Period (about the last two or three million years) may be considered potentially active.

Alignment of earthquake epicenters along a fault trace is an indicator of activity but one which is generally considered to be less compelling than proven Quaternary offset. Similarly, a permeability barrier in Quaternary deposits, a prominent air-photo lineation in Quaternary deposits, a fault trace defined by youthful fault related topographic features, or a fault trace which closely coincides with the epicentral area of a major historic earthquake are considered to be less certain evidence than proven Quaternary rupture. These and other criteria have been used to identify faults which may be significant to a project.

6. Faults are typically not singular breaks in the earth's crust by systems of breaks. Those systems include "fault zones", which are localized "shatter belts" of paralleling and connecting faults behaving as a single entity, wide belts containing several paralleling and connecting faults along which energy releases may alternate, and linear series of faults that may link and thereby pose the danger of larger magnitude earthquakes.
7. Energy release events on an active fault may alternate from one trace to another, and movement on a master fault could trigger adjustments on minor, subsidiary faults. Because of these factors, fault traces which intersect or parallel known active faults warrant special consideration during project review.
8. Losses from fault displacement are expected to be low compared to losses from earthquake shaking. It has been estimated by the California Division of Mines and Geology that between 1970 and the year 2000, fault displacement losses in California will total \$76 million. These losses will occur primarily along well recognized active faults in urban centers and in the surrounding suburban communities.
9. Although losses from fault displacement tend to be relatively low, the risks are greatly increased by inappropriate development. For example, fault movement during the 1971 San Fernando earthquake destroyed two hundred houses (average value \$25,000) and three commercial buildings (estimated value \$200,000) for a total loss of \$5.2 million.

Policies

1. All faults, active or otherwise can adversely affect structures built over or near them and need to be taken into account in the design of buildings and developments.
2. Structures for human occupancy and those whose loss would affect the public safety or the provision of needed services should not be built over the trace of an active fault.
3. Faults with characteristics described in Finding 4, above, should be classified as active. Faults with characteristics described in Finding 5 (first paragraph) should be classified as potentially active.
4. To the extent practicable, structures requiring a high degree of safety and critical structures should not be built in an active or potentially active fault zone. When such structures must be located in a fault zone, the structure should be carefully sited, and designed and constructed to withstand the anticipated earthquake stresses.
5. The effects of fault displacement are so significant that geologic investigation is warranted as a prerequisite for authorizing public or private construction in areas of known faulting.

Recommendations

1. Governments in seismically active areas should work individually and cooperatively to locate faults, classify them, and map fault zones.
2. Governments in seismically active areas should adopt plans, policies, and procedures, and enact legislation to implement the above policies.

GROUND SHAKING

Findings

1. Energy released by an earthquake is transformed into ground waves which radiate outward from their location or origin in a fault.

2. Ground shaking from surface waves is generally the most destructive earthquake effect. Severe ground shaking may occur tens of miles distant from a strong earthquake. The seismic factors influencing the observed Modified Mercalli intensities during an earthquake include: (1) magnitude of the earthquake, (2) distance of a particular site from the moving fault plane, (3) focal depth of the earthquake, (4) duration of shaking, (5) frequency content and period of the shaking, and (6) local ground conditions.
3. Ground shaking during an earthquake may be more severe on poor ground located farther away from a causative earthquake fault than on solid ground in closer proximity to the fault.
4. It has long been recognized that the performance of a structure during an earthquake is closely related to the nature of the ground on which it rests. Historical data has repeatedly demonstrated that structures sited on water-saturated surficial deposits, landslide deposits, and non-engineered fill are subject to severe damage. The damage experience in these areas is in part due to the amplification of earthquake waves in these materials and in part due to ground failure induced by the earthquake waves.
5. It is estimated that ground shaking will account for \$21 billion in damage to public and private property in California during the period 1970-2000. Most of the damage and loss of life will occur in zones of high seismic activity, such as the Bay Area, and most of the damage and loss of life will occur in structures which are built on poor ground or which do not comply with the provisions of the Field and Riley Acts, passed in 1933. (California Division of Mines and Geology, Bulletin 198, p. 7.)

Policies

1. In seismically active areas, ground conditions should be a primary consideration in the selection of land use and in the design of development.
2. In seismically active areas, structures for human occupancy should be designed to perform satisfactorily under earthquake conditions (see Table 9).

3. Structures for human occupancy, or those whose loss would substantially affect the public safety or the provision of needed services, should not be erected in areas where there is a high risk of destruction in the event of anticipated earthquake conditions.
4. In areas of high damage susceptibility from ground shaking (Zone IV on Map 3) the risks to life and investments are sufficiently high to warrant geologic-seismic and soils studies as a pre-condition for authorizing major land developments and important structures (public or private). Additionally, significant land use decisions should be based on thorough understanding of geologic-seismic and soils conditions on the parcel. Studies may be waived for construction of single family homes on approved lots and minor applications (this provision is necessary since an absolute determination is often not possible, as well as being uneconomical).

Recommendations

1. Governments in seismically active areas should work, individually and cooperatively to identify and evaluate ground conditions, relative to land use and building conditions, in their jurisdictions.
2. Governments in seismically active areas should adopt plans, policies, and procedures, and enact legislation to implement the above policies.

GROUND FAILURE

Findings

1. Ground failure occurs when stresses in the ground exceed the resistance of earth materials to deformation or rupture. This instability can be triggered by earthquake shaking, which instantaneously place high stresses on earth materials.

The manifestations of ground failure are complex and highly variable; they include numerous varieties of landslides, sloughing, liquefaction, ground cracking, lurching, subsidence and differential settlement. The type of ground failure that develops in a particular area depends on topographic, geologic, hydrologic and engineering characteristics of the ground.

2. Ground failure is not contingent on high slopes, especially under earthquake conditions. Ground failure during earthquakes has occurred on slopes of less than two percent with an open face.
3. In areas where a severe slope stability problem exists, landslide damage can best be avoided by simply not building on the unstable ground. In less hazardous areas, small landslides can be totally removed or stabilized using accepted engineering methods, including: (1) dewatering the slide by installing drainage devices, (b) buttressing the slide toes and sides with compacted soils and "keying" the engineered fill into bedrock, and (c) reducing stress by removing material from the head of the slide. Decisions need to be based on precise geologic, soils and engineering information.
4. Through good planning and careful, controlled design, landslide losses can be reduced by more than ninety-five percent (California Division of Mines and Geology, Bulletin 198, p. 29).
5. Corrective costs after construction are high compared to preventive costs, and in some instances it may not be possible to save existing structures. For example, landslide losses in the San Francisco Bay Area during the 1968-69 winter exceeded \$25 million (Taylor and Brabb, 1972). Of this total, more than \$5 million was due to landslides, soils slippage, and drainage problems reported in Contra Costa County.

Policies

1. In seismically active areas, ground conditions should be a primary determinant of land use and of the design of developments.
2. In seismically active areas, structures for human occupancy should be designed to perform satisfactorily under earthquake conditions (see Table 9).
3. Structures for human occupancy, or those whose loss would substantially affect the public safety or the provision of needed services, should not be erected in areas where there is a high risk of destruction in the event of anticipated earthquake conditions.
4. In areas prone to severe levels of damage from ground shaking, the risks to life and investments are sufficiently high to warrant geologic-seismic and soils studies as a pre-condition for authorizing public or private construction.

Recommendations

1. Governments in seismically active areas should work individually and cooperatively to identify and evaluate ground conditions, relative to land use and building conditions, in their jurisdictions.
2. Governments in seismically active areas should adopt plans, policies, and procedures, and enact legislation to implement the above policies.

FLOODING

Findings

1. Historic records have repeatedly shown that fault displacement and accompanying ground shaking are capable of causing severe flooding. Flooding can be triggered by dam failure or levee failure, or by tsunamis and seiches.
2. Because many dams create terminal storage and serve as distribution reservoirs for municipal water systems, they must necessarily be sited on high ground adjacent to population centers. Thus the rapid failure of an important dam would lead to catastrophic damage to the downstream population.
3. Small reservoirs and stock ponds frequently are non-engineered structures and they may not have adequate spillways. They can pose severe flood hazard to localized areas below them, with or without earthquakes.

Policies

1. Dam and levee failure, as well as potential inundation from tsunamis and seiches, should be a significant consideration in land use planning.
2. Dams (and their empoundments) and levees should be designed to withstand the forces of anticipated earthquakes at their locations.
3. Dams (and their empoundments) and levees should be regarded as critical facilities that should not be sited over the trace of an active fault.
4. The potential effects of dam or levee failure are so substantial that geologic and engineering investigation is warranted as a prerequisite for authorizing public and private construction of either the facilities or development in affected areas.

Recommendations

1. Governments in seismically active areas, or areas subject to flooding resulting from seismic activity should work individually and cooperatively to evaluate facility vulnerability and identify areas where flooding could result from earthquakes.
2. Governments in seismically active areas should work to establish adequate standards and tests for dams and levees.
3. Governments in seismically active areas should adopt plans, policies, and procedures, and enact legislation to implement the above policies.

COUNTY GEOLOGY

Findings

1. Seismic activity is an integral part of the geologic forces that have produced Contra Costa County's physical setting and are continuing to shape its landscape. The geology of the Bay Area region is substantially the result of the continuing movement of the "Americas Plate" against the crustal plate that underlies the Pacific Ocean.
2. Because of its geologic setting in the active and dynamic central Coast Ranges of California, geologic structure in the County tends to be complex. The geologically recent uplift of the Briones Hills and Diablo Range has also created a situation where semi-consolidated rock formations of Pliocene age underlie steep hillsides. These conditions can pose serious engineering problems and in some areas long-term stability is difficult to achieve even if extraordinary precautions are incorporated into site grading and drainage design.
3. Superimposed on the pattern of uplift and deformation which characterizes the central Coast Ranges of California are the processes of erosion and sedimentation which have combined to form the County's northwest trending ridges and valleys. The modern cycle of erosion has given rise to V-shaped valleys and steep slopes. As erosion undercuts slopes, the equilibrium of the hillsides is constantly being disturbed, triggering various types of slope failure, including major landslides.

4. Some of the portions of the County, including the Bay Plain, and Delta lowlands are geologically very young. These areas are underlain by poorly consolidated alluvial and estuarine deposits which are water saturated at shallow depth and possess many adverse engineering characteristics. Such areas tend to have a low seismic stability and be prone to excessive amounts of damage as a result of ground shaking and associated ground failure.

Policies

1. Public policy regarding public and private development should recognize that Contra Costa County is situated on a particularly active and dynamic part of the earth's crust which is presently undergoing deformation. The decision-making processes should give careful consideration to geologic and soils information.
2. Geologic conditions should be a primary consideration in the selection of land use and in the design of development in Contra Costa County. The General Plan should encourage the retention of high risk areas in low occupancy or open forms of land use. It should discourage the expansion of public commitment to development of high risk areas without appropriately detailed geologic and/or soils investigations.

Recommendations

1. The Contra Costa County Planning Department should develop an administrative map primarily for project review operations, based on the mapping of the U.S. Geological Survey, and classifying geologic formations according to their characteristics for land use appropriateness.
2. The County should require geologic and/or soils information to be submitted for Environmental Impact Reports, and entitlement applications, for all major land development projects in areas of substantial risk, in accordance with the administrative map. Where warranted by the availability of published and unpublished data studies should also be required for minor applications.
3. Contra Costa County should promote, encourage, and/or contract for special geologic studies in problem areas with agencies such as the U.S.G.S. and California Division of Mines and Geology.

LOCAL SEISMIC ACTIVITY

Findings

1. Contra Costa County has experienced more than six major earthquakes in the relatively short time that written records have been kept (roughly, since 1800). Some of these originated on faults within the County; the remainder occurred on faults elsewhere in the Bay Area. All took place in the seventy year period between 1836 and 1906; none have happened in the last sixty-eight years.
2. The County has experienced approximately six hundred earthquakes on faults inside or near its boundaries since general purpose seismograph monitoring began forty years ago in 1934. These included fifteen events of magnitude 4.0 or greater. Many of the earthquakes can be related to known faults and constitute evidence of their activity.
3. Microseismic monitoring for Contra Costa County, still incomplete, is available only since 1970. Data shows concentrations of activity along the Hayward fault, the Calaveras fault, Concord faults, and the seismic zone east of Danville.
4. Prior to 1906, the Carquinez Strait-Suisun Bay area reportedly exhibited the highest seismicity of any region in central California.

Policies

1. Public policy in Contra Costa County must recognize that the County is in an area of prevailing high seismic activity in which earthquakes of all levels of magnitude are likely to occur.
2. In an area of high seismicity, such as Contra Costa County, fault traces which are marked by an alignment of epicenters should be afforded special consideration in required geologic reports.

Recommendation

1. Contra Costa County should actively seek to obtain countywide coverage of the monitoring of microseismic activity.

EARTHQUAKE PROBABILITY

Findings

1. Because of the complexities of the earthquake phenomenon, the short documented history of Bay Area seismic activity, and the inadequacies of current technology, the prediction of the magnitude, time of occurrence, or locations of earthquakes is presently unreliable.
2. Statistical techniques do allow estimates to be made of the frequencies of different magnitude earthquakes on the major faults affecting Contra Costa County (Table 4).
3. Based on historical seismic and geologic information, estimated maximum earthquake parameters have been developed for selected active faults affecting Contra Costa County (Table 5).
4. One approach to the evaluation of earthquake risk is to consider the probability of a damaging earthquake occurring during the life of existing or proposed structures. Statistical analysis of historic Bay Area earthquakes indicated that over a fifty year period there is a greater than fifty percent probability of a severe earthquake on each of the major Bay Area fault systems (San Andreas, Hayward, and Calaveras). Additionally, it is reasonable to infer that earthquakes which have caused death and property damage have emanated from faults which trend through Eastern Contra Costa County.

Policy

1. Public policy in Contra Costa County should recognize that a severe (potentially damaging) earthquake is sufficiently likely to warrant consideration in planning, building and development programs. Structures should be designed and constructed to perform satisfactorily under earthquake conditions (see Table 9).

Recommendations

1. The estimates of earthquake frequencies and magnitudes, and the estimated maximum earthquake parameters should be included in the Seismic Safety Element for adoption by the County and consideration by other jurisdictions.

2. The County Planning Department, in cooperation with other organizations and jurisdictions, should refine the estimates of Tables 4 and 5.

LOCAL FAULTS

Findings

1. Earthquake faults are inherent features of Contra Costa County's geologic structure, and inherent in the geologic processes that produced its landscape.
2. Earthquake faults are numerous in the County--but not "everywhere". Most are parts of systems that parallel the San Andreas fault (which is not present in the County) or radiate outward from Mt. Diablo.
3. Most of the mapped bedrock faults in the County are minor, short in length, and are not known to be active.
4. All faults, to varying degrees, should be given consideration in the design of developments and in site preparation. For example, it should be recognized that many minor, presumed inactive faults in the County intersect active or potentially active faults. It is conceivable that movement on the master fault could trigger adjustments on minor cross faults or adjacent subparallel faults. It should also be noted that the engineering character of the crushed material in the fault zone may effect foundation and drainage design.
5. There are three levels of risk related to the hazard posed by fault rupture: (a) highest risk to structures straddling the trace in an active fault zone, (b) intermediate risk to structures sited on an active fault zone, but not sited on a trace, and (c) lowest risk to structures sited outside of an active fault zone.
6. There are several strong arguments for requiring minimum setbacks from active fault traces. The principal advantages are: (a) to provide a minimum "safety factor" for structures and occupants of structures sited in an active fault zone without placing an unnecessarily stringent restriction on land use in such fault zones, (b) to allow owners of undeveloped property to know what the policy of the County is, and (c) to give the Planning staff and Planning Commission a basic guideline in reviewing development proposals.

7. It is very important to carefully analyze undivided acreage at the earliest possible stage in the development process with respect to seismic hazards to determine the suitability of land for development. Mistakes made in subdivision and building are virtually impossible to correct through other than the redevelopment process.
8. An impressive body of information regarding faults exists for Contra Costa County. The principal sources of data include the mapping of the U.S. Geologic Survey, California Division of Mines and Geology, field studies performed by registered geologists (e.g., site trenching) and studies conducted by universities and research institutions. This information is suitable to accomplish many policy planning and project review functions, and generally to guide land planning.
9. In general, fault mapping in the County is not accurate to the level of detail used in ordinance maps because the locations of individual fault traces has not been precisely determined and because faults are variable in the characteristics.
10. Because of the diversity of sources, there is a need to compile a fault map of Contra Costa County which maps fault traces and shows the location of delineated Special Studies Zones. Such a map would be useful in the administration of project reviews and in the administration of development ordinances.

Policies

1. Private development proposals within Special Studies Zones must give special consideration to the potential for surface faulting and seismically triggered ground failure. In general, detailed geologic studies will be necessary to accurately map fault traces and evaluate ground conditions on the site. Public works and utilities installations should be subject to the same standards that are applied to private development.
2. In exercise of their responsibility to provide for the public safety in Special Studies Zones, public building decisions made by the County should be guided by knowledge of fault conditions on the site. Even in instances where an alternative site is not (readily) available, final judgments should be based on knowledge of the degree of risk and the consequences of failure.

3. Structures intended for human occupancy must not be erected over an active fault trace.
4. Inactive fault traces should be given consideration in the review of proposed projects.
5. To the extent practicable, structures which affect the provision of needed services (e.g., highway interchanges, utilities) should not be erected over the trace of an active or potentially active fault. Where it is deemed essential to do so for the public welfare, these structures should be designed to accommodate or minimize the effects of fault displacement and seismically-triggered ground failure.
6. Structures intended for human occupancy should be adequately set back from active and potentially active fault traces. Minimum setbacks should take into account the varying degree of seismic risk and consequences of failure.
7. Land in the setback "zones" along active and potentially active fault traces should be utilized for open forms of land use that could experience displacement without endangering large numbers of people or create secondary hazards. Examples are yards, greenbelts, parking lots, and non-critical storage areas. Roads, particularly those which carry large volumes of traffic, should be sited over active faults only where other alternatives are impractical.
8. Comprehensive geologic and engineering studies should be required for any critical structure, whether or not it is located within a Special Studies Zone.

Recommendations

1. Contra Costa County, through its Planning Department, should prepare a "fault map" for use in the administration of project reviews (e.g., Environmental Impact Reports and mandatory referrals) and in the administration of development ordinances. Preferably, this map should be done on a countywide basis and in the form of a map series at a scale of 1:24,000 (1" = 2000') to make efficient use of U.S.G.S. and California Division of Mines and Geology (D.M.G.) fault information. The map should show: (a) faults, classified by activity status and locational certainty, (b) fault zones or Special Studies Zones, and (c) fault-related hazardous conditions and related information. The map's information

should include but not be limited to the 1973 fault mapping done for the County by the California Division of Mines and Geology pursuant to S.B. 520.

2. This "fault map" and policies for its use should be adopted by the County, preferably as part of its General Plan (either in the Seismic Safety Element or special General Plan supplement or alternatively as a matter of policy such as the County's Environmental Impact Report processing procedures) by the Planning Commission and Board of Supervisors.
3. The conditions of adoption of the fault map should direct that it be considered in the making of improvements by all agencies under the purview of the Board of Supervisors. These agencies should obtain geologic and engineering studies equivalent to those required of private developments for their own projects.
4. The conditions of adoption of the fault map should direct that it be considered in project reviews performed by County agencies, including Environmental Impact Reports, mandatory referrals ("65402" reviews), and regional clearinghouse reviews. These reviews pertain to private projects and the projects of other levels of government as well as County projects.
5. The conditions of adoption of the fault map should direct that County agencies consider the map in their administration of development ordinances, including the zoning and subdivision ordinances.
6. The County's zoning and subdivision ordinances should be revised to require the consideration of seismic safety factors, including slope stability and seismically-related flooding.
7. The conditions of adoption of the fault map should contain the above policies (or adaptations) as provisions, and should provide for the following minimum setback requirements with the Special Studies Zones of active or potentially active faults.
8. No building for human occupancy should be sited closer than fifty feet to an active fault trace*unless a geologic report prepared by

*An active trace is defined as a trace which disturbs geologic units of known or inferred Holocene age.

a geologist registered in the State of California indicates that a lesser setback is appropriate. Ordinarily such a determination will be based on geologic factors such as the character of the fault, local ground conditions, and depth of the water table.

9. Provisions should be made to require geologic and/or soils investigations in areas found to be potentially hazardous. Ordinances and regulations requiring studies should be flexible, allowing for the exercise of professional judgment. The standards for site analysis should reflect the degree of awareness of the hazard and the nature and scale of the proposed development. Depending on circumstances, the requirement for reports could be phased or staged, with an initial requirement for a reconnaissance report to be followed by a geologic hazards report or a preliminary soils report, where appropriate. (The purpose of the reconnaissance report is to identify areas that may require special management and to recommend an exploration program to define and delineate any geologic hazard or potentially hazardous soil condition. The purpose of the subsequent studies, where needed, is to accurately identify developable areas and to recommend means of mitigating potentially hazardous conditions.)

GROUND SHAKING AND GROUND FAILURE

Findings

Ground Shaking

1. The ability of a structure to resist earthquakes is greatly influenced by the ground conditions at the site. Historically, structures which have been built on swampy, continually wet, unconsolidated sediments; non-engineered fill; and landslide deposits have sustained severe levels of damage during earthquakes.
2. The effect of local geologic conditions on earthquake waves appears to be strongly influenced by the degree of water saturation. In areas where the water table occurs at depths of approximately twenty feet or greater, there is no reason to expect severe amplification of ground motion. However, it should also be recognized that during the rainy winter months the water table is effectively raised to the surface in many local areas.
3. Based on comparison of a number of seismograph records from "bed-rock" and "firm alluvial" sites in California, there appears to be

little reason to anticipate significantly more intense shaking on sites underlain by firm, dry, alluvium. There will be some systematic differences in the characteristics of the ground motion (e.g., predominant period will be relatively longer in alluvial areas; accelerations and displacements tend to be relatively higher in alluvial areas). Any of these differences may affect the structural design of sophisticated structures.

Ground Failure: Liquefaction

1. Catastrophic failures in recent earthquakes have provided a sobering reminder that liquefaction poses a major threat to the safety of engineered structures. Major landslides, settling and tilting of buildings on level ground, and failure of water retaining structures have all been observed in recent years as a result of this type of ground failure.
2. Within the Bay Area, abundant evidence of slope failure attributable to liquefaction can be seen in photographs taken after the 1906 San Francisco earthquake. It should be emphasized that: (1) great earthquakes anywhere in the Bay Area are capable of triggering liquefaction in Contra Costa County, and (2) in many instances it is possible to evaluate the liquefaction potential of granular material rather inexpensively.
3. Historically, ground failure in its various forms, including liquefaction, has been a problem in areas of continually wet, unconsolidated geologic units. In Contra Costa County the areas which are most susceptible to ground failure include the geologically young sediments of the San Francisco Bay estuary, including the Delta lowlands. Non-engineered fill and landslide deposits are also potentially hazardous under earthquake conditions.
4. Within the area of continually wet unconsolidated deposits (Zone IV), the degree of seismic risk is closely related to local ground conditions. A site underlain by a great thickness of potentially unstable material (soft, compressive muds and loose, clay-free sands, etc.) is extremely hazardous. It should be recognized that such a site has a very limited development potential. Conversely, a site underlain by a minimum thickness of soft muds possesses a much better development potential. Utilizing existing knowledge of foundation engineering, such a site could be made suitable for a variety of land uses.

Ground Failure: Landslides

1. Landslides, rock falls, avalanches, mud and debris flows, and general gravitational movements of loose and weathered rock and soil are a serious obstacle to urbanization of hillsides in Contra Costa County. Moreover, the seismic history of the San Francisco Bay Area indicates that slope failures of all types are major effects of ground shaking in moderate to great earthquakes.
2. Most engineering geology reports submitted to Contra Costa County in behalf of private development projects recognize that hillsides of the Orinda Formation and related formations are prone to landsliding. In relatively steep slopes, and in sheared or deeply weathered material, long term stability is difficult to achieve, even if extraordinary and expensive precautions are incorporated into site grading and drainage designs.
3. In recent years a number of jurisdictions in Southern California have required engineering geology reports for public and private projects in areas of known geologic hazard. These investigations, along with the development regulations of these jurisdictions, have been remarkably successful in reducing the year-to-year dollar loss due to landslides and they provide a higher degree of seismic safety.
4. It should be evident that technical review of land use proposals is critical to achieving effective compliance with regulations requiring geologic reports.
5. A principal cause for concern in developing hillside areas is that, although individual structures may be sited safely, roads and other public service facilities seldom can completely bypass unstable areas. These long term costs may be great and generally must be borne by the community as a whole rather than by the developer.

Policies: Ground Shaking, Ground Failure and Landsliding

1. The County General Plan and its component area plans should recognize local ground conditions as a primary determinant of land use. Within the area of highest damage susceptibility (Map 3, Zone IV) land uses not involving substantial human occupancy should be given a high priority. In essence, the General Plan should encourage the retention of high risk areas in low occupancy

or open forms of land use. Wherever practical the General Plan should discourage urban or suburban development in Zone IV, while recognizing that there are uses appropriate to such areas. Some industries, for example, need to locate near waterways, and much can be done to minimize risk through extraordinary site, foundation, and drainage design. Parallel recommendations apply to areas underlain by deposits classified as having a high liquefaction potential and hillsides classified as possessing a high landslide susceptibility.

2. To the extent practicable critical facilities, structures involving high occupancies and public facilities should not be sited in areas of highest damage susceptibility (Map 3, Zone IV). Where it is deemed essential to do so for the public welfare, these structures should be sited, designed and constructed with due consideration for the potential for earthquake damage due to ground shaking, associated ground deformation, and seismically-triggered flooding. Parallel recommendations apply to areas underlain by deposits classified as having a high liquefaction potential and hillsides classified as possessing a high landslide susceptibility.
3. In exercise of its responsibility to provide for the public safety in areas which are considered potentially hazardous in the event of an earthquake, approvals for public and private development projects should be contingent on geologic and engineering studies which define and delineate potentially hazardous geologic and/or soils conditions and recommend means of mitigating these adverse conditions.

Recommendations

1. Contra Costa County, through its Planning Department should compile an administrative map series delineating areas which may be hazardous during earthquakes. The proposed map series could be presented in the form of a Seismic Susceptibility Map, Liquefaction Potential Map and Landslide Susceptibility Map. Preferably this mapping should be done on a county-wide basis and at a scale of 1 inch = 2000 feet. The U.S.G.S. topographic quadrangle maps would form an ideal base for this information.
2. The proposed maps in Recommendation 1 and the policies for their use should be adopted by the County, preferably as part of its General Plan (in the Seismic Safety Element or special General Plan Supplement).
3. The conditions of adoption should provide for periodic updating and revision of maps which delineate potentially hazardous areas. A

procedure should be developed to provide for technical review of proposed changes prior to any formal adoption by the County.

4. The conditions accompanying the adoption of the proposed map series should direct that it be considered in the planning of improvements by all agencies under the purview of the Board of Supervisors.
5. The conditions accompanying the adoption of the proposed map series should direct that it be considered in project reviews performed by County agencies including Environmental Impact Reports, mandatory referrals ("65402" reviews) and regional clearinghouse reviews. These reviews pertain to private projects and the projects of other levels of government as well as County projects.
6. The conditions accompanying the adoption of the proposed map series should direct that County agencies consider the map in their administration of development regulations, including the zoning and subdivision ordinances.
7. The subdivision and zoning ordinances should be amended so that they specify that geologic, soil, and seismic safety factors are to be taken into account during project review and that appropriate geologic and/or soils investigations can be required in areas considered to be potentially hazardous. Standards for required reports should reflect awareness of the hazard as well as the nature of the project. As noted earlier in this report, requirements for geologic and/or soils investigations and reports, could be staged or phased, depending on the circumstances.
8. Required reports should be given technical review to ensure that the scope and direction of the investigation is appropriate for the nature of the project and its geologic setting.

FLOODING AND SEISMICITY

Findings

Delta Levees

1. Much of the Delta area is underlain by an irregular blanket of sponge-like peat, composed of decaying organic matter. The adverse engineering characteristics of this material include high water content, low shear

strength, high compressibility, low bearing strength and high combustibility. Even with modern technology the Delta peat places severe limitations on levee design, construction and maintenance.

2. The Delta peat is very hazardous seismically. Historic evidence of damage as well as field measurements of ground motion at low strain levels suggest that areas underlain by peat and other materials of similar engineering characteristics may experience an incremental increase in intensity as high as two to three and one-half Modified Mercalli Units compared with hard bedrock. Additionally, fine-grained sand bodies which are interbedded with and underlie the peat are also susceptible to shaking and some of these sands have a high liquefaction potential.
3. The California Department of Water Resources recognizes a three-fold classification of levees: (a) flood control project levees (engineered structures maintained to federal standards); (b) direct agreement levees (repaired by the Corps of Engineers following major breaks and maintained to federal standards); and, (c) non-project levees (non-engineered structures which are not forced to meet absolute standards of safety or performance).

Within Contra Costa County there are no flood control project levees and the only direct agreement levees are those on islands which form the southern boundary of the San Joaquin River (including part of the levee which encompasses Jersey Island and all of the levees encompassing Bradford and Webb Tracts). Thus an estimated eighty to ninety percent of the Delta levees of Contra Costa County are non-project levees.

4. The non-project levees are non-engineered structures which are not stabilized, and are non-uniform in cross-section. According to the California Department of Water Resources, non-project levees are deteriorated and do not provide an adequate level of public safety.

The vulnerability of the levees to being overtopped is well illustrated by events of mid-January, 1973. According to the Contra Costa County Office of Emergency Services, levees were overtopped or within a few inches of being overtopped on at least five islands in the County. Additionally, all islands are subject to inundation as a result of levee failure. Although the mechanism of failure is variable, the collapse of a segment of levee is commonly related to the adverse engineering characteristics of the peaty soils.

5. All Delta levees are constructed and maintained solely for the purpose of flood control. There are no standards against which the level of seismic risk is judged and there has generally been no assessment of the probable effects of seismic loading on the levees or the underlying peat. The present level of seismic risk in the Delta islands is the highest in history. Through the years investments have grown, the life loss potential has increased and the stability of the levees has decreased. Available information strongly indicates that the entire levee system is vulnerable to failure during a severe earthquake, and that the potential hazard posed by earthquakes is greatest during periods of high water level in the Delta--when levees are under high stress.

Dams

1. Major dams are the most critical structures in Contra Costa County in terms of potential life loss. Seismic concerns should be an overriding consideration in the inundation area below dams of questionable seismic response characteristics.
2. The California Division of Safety of Dams within the Department of Water Resources has jurisdiction over the twenty-two largest dams in Contra Costa County. The Division of Safety of Dams has broad powers over dams and reservoirs to ensure that they provide adequate standards of public safety. After the near catastrophic failure of a hydraulic fill dam during the 1971 San Fernando earthquake (the crestal elevation of the dam dropped eighteen feet during the six to eight seconds of strong ground shaking), the Division of Safety of Dams required owners of hydraulic fill dams to conduct studies of the effect of seismic loading on their structures. Late in 1972 East Bay Municipal Utility District submitted a report to the regulatory agency on the seismic response characteristics of San Pablo Dam, the only hydraulic fill structure in Contra Costa County. The report is presently being reviewed by the Division of Safety of Dams, who will make a judgment as to the adequacy of the study which was undertaken and the soundness of its conclusions.
3. Under earthquake conditions it appears reasonable to anticipate extensive slumping, cracking, fissuring, and fragmentation of the embankments of a number of non-engineered, small, earthen dams in the County. The lack of both foundation preparation and engineering

embankment construction makes many of these structures highly susceptible to damage and failure. It is equally important to recognize that failure of small dams is more commonly related to inadequate spillway capacity or lack of proper maintenance.

Tsunamis

1. Nineteen tsunamis have been recorded at the Golden Gate Tide Gage during the period 1868-1968. During this period maximum wave height recorded at the Golden Gate was 7.4 feet.
2. As inferred from the 1960 and 1964 tsunamis in San Francisco Bay, tsunami waves are attenuated by fifty percent at the Richmond-San Rafael Bridge tide gage and the waves are completely dissipated as they reach the Carquinez Strait.
3. The greatest threat from tsunami inundation in Contra Costa County appears to be in the Richmond harbor area. In this area runup may extend as far inland as the ten foot topographic contour. The actual extent of runup depends on several complex factors including tidal stage, tidal height, height of the tsunami at the Golden Gate, wind and water currents, and the configuration of the shoreline.
4. Historically, the greatest hazard posed by tsunami waves in San Francisco Bay has been from swift currents. In the past, tsunami-generated currents have damaged moored boats and marinas, and these currents are also a threat to people engaged in shoreline recreation activities and harbor traffic. This points up the need to have an adequate warning system.

Policies

Delta Levees

1. Owing to the extremely high degree of seismic risk, very thorough review should be given to future growth and development in the Delta lowlands (the area subject to inundation in the event of levee failure).
2. Agricultural and other land uses not involving substantial human occupancy should be specified for areas of exceptionally high seismic hazard, such as the Delta islands.

3. To ensure that seismic risk does not exceed acceptable levels, require soils and geologic hazard reports on development projects. Such reports should assess the stability and dynamic response of the levees, the underlying soils and the consequence of failure.

Dams

1. Stringent controls should be applied to all land use in areas downstream from or protected by water-retaining structures that are substandard or questionable with respect to their dynamic response characteristics, or that lie within an active fault zone or where the potential for massive landsliding into the reservoir exists.
2. In fulfilling its role of promoting seismic safety, the General Plan should give appropriate consideration to seismic safety factors in the potential inundation area below major dams.

Tsunamis

1. Structures for human occupancy, and particularly critical structures, and potentially dangerous commercial or industrial facilities (e.g., plants for the manufacture or storage of explosive, flammable or toxic materials) must be protected against tsunami hazard.

Recommendations

Delta Levees

1. Restrict land uses to those that are economically essential and notify owners, builders, and occupants of areas subject to inundation of the hazard.
2. Specify that open space land use is an appropriate devise for areas of exceptionally high seismic hazard, such as the Delta islands.
3. To ensure that seismic risk does not exceed acceptable levels, require soils and geologic hazard reports on all land transactions subject to public review. Such reports should assess the stability and dynamic response of the levees, the underlying soils, and the consequence of failure.

Dams

1. Land use planning and regulations downstream from dams of questionable seismic response might include:
2. Restricting land use to those that are economically essential and warning owners, builders, and occupants of areas subject to inundation of the hazard.
3. Where economically feasible, and without encouraging a false sense of security, constructing restraining or diversion structures to limit the inundation potential.
4. Instituting an appropriate communication system to warn of impending failure.
5. Adopting and implementing evacuation plans.
6. It is recommended that the County adopt an ordinance regulating the design and construction of dams not under the jurisdiction of the state. Such an ordinance might be modeled after ordinances adopted by other Bay Area counties.

Tsunamis

1. Although no devastating tsunami has been recorded in San Francisco Bay, and the likelihood of one may be small, the possibility still exists. Where safety is critically important, and particularly in the Richmond harbor area, further detailed study of tsunami hazard prior to development of such structures is advisable. Additional restriction does not seem warranted at this time.

STRUCTURAL SAFETY AND RISK

Findings

1. Anyone who lives or builds in Contra Costa County necessarily assumes seismic risk. The County, together with most of the Bay Area, is in a region of high seismicity.
2. The level or risk to persons or to property may not be adequately perceived since most of the County's or the Bay Area's population was born or moved here subsequent to the last major earthquake.

3. Considerations of cost and practicality aside, our technology enables us to reduce the loss of life or exposure to severe injury from seismic causes, but probably not the risk of severe and widespread damage to structure and property.
4. Considerations of economics, institutional capabilities (law, citizen acceptance, etc.), and technological impracticalities appear to preclude the full use of our technological capabilities to mitigate risk in the short-run. Now and for some time in the future, the extent of seismic protection the County's citizens will enjoy largely depends on what they will accept, and partially on what they can afford.
5. There is a need for the revision and strengthening of the existing building codes as a means of improving design provisions for seismic safety. Damage to structures and facilities during recent earthquakes suggest several specific areas that require attention.
6. Damage to high-rise buildings during recent earthquakes indicates that evacuation of a weakened structure prior to the occurrence of a severe aftershock, panic and/or fire, or the creation of a safe environment within the building is extremely important, particularly since parts of some of these buildings are beyond the reach of emergency equipment.
7. The performance of freeway overpasses during the San Fernando earthquake was clearly unsatisfactory. This points out the need for the State to perform a structural study of freeway overpasses in the County and reinforce those found to have structural deficiencies.
8. Seismic safety of existing non-conforming structures should be evaluated in terms of (a) site location with respect to known or potential geologic hazards (the hazard maps accompanying the Seismic Safety Element will be suitable for this purpose), (b) use or occupancy of the structure, (c) ability of the structure to resist earthquakes, and (d) life of the structure.
9. Little progress is being made on the greatest of existing hazards confronting Californians: The thousands of collapse-hazard older buildings in which people live and work. An implementation program should concentrate on older buildings (pre-1933) and buildings sited in potentially hazardous settings.
10. The next severe Bay Area earthquake will provide engineers, geologists, planners and seismologists with a great amount of information on the

performance of slopes, various types of ground and structures throughout Contra Costa County.

Policies

1. The County's primary seismic safety goal should be the protection of the lives of everyone present in its jurisdiction in the event of an earthquake.
2. The County's secondary goals, in order of priority, should be to protect people from serious injury, to ensure that necessary services are provided, and to ensure that economic and physical recovery are rapid.
3. The County should give first emphasis to ensure that new construction, projects, and developments conform to its seismic safety goals.
4. The County should give next emphasis to the mitigation of existing hazardous buildings and conditions in accordance with the order of priority and its goals, and in keeping with its resources to diminish hazards.
5. Every structure in Contra Costa County should be designed and constructed so as to ensure that acceptable levels of seismic risk will be achieved.
6. Every high-rise building should be designed and constructed to provide for the evacuation of occupants and/or for the creation of a safe environment in case of a substantial disaster, such as a severe earthquake or fire.
7. Every hazardous structure in Contra Costa County should be identified, particularly critical facilities.
8. It should be the expressed policy of Contra Costa County to see that collapse-hazard buildings, and particularly public facilities, be reconstructed to provide an adequate level of public safety or be abated through reasonable, but effective, means.
9. After a severe earthquake, it should be the expressed policy of Contra Costa County to see that scientific information is fully utilized to guide reconstruction and redevelopment plans in heavily damaged areas.

Recommendations*

1. The "Scale of Acceptable Risk" (Table 9) should be included in the Seismic Safety Element, for adoption, as a basis for administrative direction in carrying out the seismic safety goals as they pertain to structures.
2. It appears appropriate to adopt interim building standards that will provide a higher level of seismic safety for the public without imposing an undue hardship on developers. The 1933 Field Act, which governs school design in California, illustrates the effectiveness found in code revisions related to seismic safety and disaster preparedness. Consequently, the Board of Supervisors should direct the Building Inspection Department at its discretion, to make recommendations for the revision and amelioration of the existing building codes as a means of improving design provisions necessary for seismic safety; and to adopt the 1976 code revisions as soon as possible.
3. Require that all designs for high-rise buildings include either an acceptable plan and procedure for the evacuation of occupants and/or the creation of a safe environment within the building for the occupants. Such plans and procedures are to be approved by appropriate agencies of county government prior to the filing of the drawings for the purpose of obtaining a building permit and shall be maintained as a public record for each building, to be referred to in cases of emergency.
4. A survey of buildings is needed to evaluate structural hazards and to institute a program to correct them. Because California may create an Earthquake Commission which probably would establish criteria for such a survey, it is recommended that the County wait a reasonable time (two years following Seismic Safety Element adoption) for the State criteria before initiating a program of its own. If no State program is available after two years, the County Planning Department should recommend one.
5. It is recommended that the County obtain structural engineering services to investigate the design and construction of existing structures. As a practical first step in identifying hazardous

*The policies and recommendations of other chapters also deal with the mitigation of risk.

structures, it is suggested that this program begin with a survey of building types that are known to be the most hazardous in areas where the potential hazard from ground rupture, ground shaking or slope failure is greatest. Additionally, certain critical structures and facilities should be investigated to determine if they would remain functional after undergoing severe ground shaking. These critical structures should include hospitals, fire houses, police facilities, disaster response coordination center and its communications network and freeway interchanges.

6. Ordinances should be enacted that would require amortization and eventual removal of non-conforming structures in the greatest danger, starting with those that endanger the greatest number of lives such as schools, hospitals, office buildings, apartment buildings, and auditoriums. Phasing out of older buildings through redevelopment might be a practical means of reducing injuries and loss of life in future earthquakes.
7. Abatement ordinances for all types of hazardous buildings should proceed on a relative safety basis, weighing life loss potential against economic and social considerations.
8. The General Plan should provide for changes in circumstance that would follow a substantial disaster. Final judgments on land use in heavily damaged areas should be based on scientific knowledge of the risks involved and consequence of failure.
9. Contra Costa County, through its Planning and Building Inspection Departments, should provide for technical review of all required geologic and related engineering reports.
10. Provision should be made for review of the structural safety aspects of the Seismic Safety Element after two years. This review should give special attention to new information. It should also focus on the effectiveness of the implementation program.

CRITICAL STRUCTURES

Findings

1. The Field Act was placed in the statutes by the California Legislature shortly after the collapse of a school building in the 1933

Long Beach earthquake. This act places the construction of public school buildings under the supervision of the State for the protection of property and life.

2. The Field Act did not include a geologic siting requirement until 1967. Consequently, some pre-1967 Field Act schools in the County may be sited in areas of unstable ground; others are on or immediately adjacent to active faults.
3. The success of "specialized" building standards coupled with competent geologic site analysis is illustrated by the California experience that no school built under the Field Act has failed during California earthquakes. Conversely, even a low to moderate magnitude earthquake is capable of producing severe damage to a school building which possesses important structural deficiencies.
4. Most of the hospitals in the County are modern structures which have been built under the authority of modern building codes. However, there are some hospitals which appear to be sited on or very near the traces of active faults. Additionally, there are some older structures whose ability to resist earthquake shaking needs to be investigated.
5. Massive damage (including partial collapse) to hospitals during the 1971 San Fernando earthquake has led the California State Legislature to enact a statute which places the construction of hospitals under the supervision of the State, including both new hospitals and additions or remodeling to existing structures.
6. As long linear elements, it is generally not possible for highways and public service utilities to avoid hazardous areas. Nevertheless, crossings of faults and unstable ground should be minimized.
7. Because of their design and construction, many freeway bridges are vulnerable to total or partial collapse as a result of strong ground shaking. Additionally, interchanges which are sited in areas prone to landsliding, liquefaction or other types of ground failure are exposed to additional risk from these factors.
8. Massive damage to the water supply and sewer systems is an expectable consequence of a severe earthquake. Most of the destruction in the 1906 San Francisco earthquake resulted from fires that could not be controlled because of shattered water

mains. Most recently, the 1971 San Fernando earthquake produced such extensive damage as to practically require a completely new water system for the City of San Fernando.

9. Structures for the distribution of electricity which are sited on faults or unstable ground are susceptible to extensive damage. However, well sited structures have performed well during recent California earthquakes. It should be recognized that transmission lines and their supporting towers must cross areas of questionable stability and therefore are subject to disruption.

Policies

1. Decisions of the location of critical structures and facilities should be based on a thorough consideration of all factors, including need for the facility, suitability of the site for the type of land use proposed, availability of alternative sites, etc. Final decisions should be based on knowledge of the risks involved and the consequences of failure.
2. Critical structures and facilities should not be located in "high-risk" areas. However, where it is in the overriding public interest to locate critical facilities in these areas, special precautions should be taken to enable those facilities to withstand anticipated hazards. In particular, the County of Contra Costa should not locate critical facilities under its jurisdiction in "high-risk" areas. All public agency high-occupancy and critical structures should be reviewed by the Planning Agency relative to seismic safety in the course of "mandatory referral" reviews.

Recommendations

1. Professional soils and geologic-seismic investigations should be required for all critical facilities and high occupancy structures. Soils reports should be prepared or approved by a registered civil engineer specializing in soils engineering; geologic-seismic reports should be prepared or approved by a registered geologist specializing in engineering geology. Final subdivision maps should reference soils and geologic-seismic reports and the final map should be signed by the professional soils engineers and geologists who prepared or approved the reports.

2. Project reviews performed by County agencies, either reports prepared for County projects or the review of other agencies' projects, should address seismic safety and the adequacy of seismic safety information for performing these reviews.
3. The County Zoning Ordinance should be reviewed and amended if necessary, to require site plan reviews for all private high-occupancy structures and critical facilities.
4. In cooperation with other jurisdictions and departments, the facilities indicated in this chapter should be individually reviewed for their seismic safety by a licensed structural engineer.

CONTRA COSTA COUNTY PLANNING DEPARTMENT
COUNTY ADMINISTRATION BUILDING--MARTINEZ, CALIFORNIA 94553

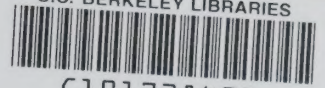
Anthony A. Dehaesus, Director of Planning

Participating Staff Members:

Charles A. Zahn, Planning Coordinator
Program Administrator and Principal Author

W. Darwin Myers, PhD, Planning Geologist
California Registered Geologist
Project Planner and Contributing Author

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